june,

nlgi spokesman

journal of the national lubricating grease institute

Flow Properties of Lubricating Oils Under Pressure

S. J. HAHN, DR. H. EYRING, I. HIGUCHI and DR. T. REE

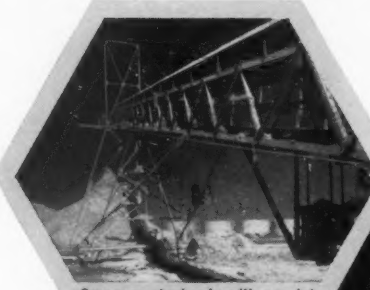
The Studebaker-Packard Twin Traction Differential – Its Problems and Limitations

O. K. BUTZBACH and PAUL IZDEPSKI

Packaging – An Essential Service

A. D. MURPHY

"In 14 months...not a single bearing lubrication failure with lithium-base grease!"


Conveyor-stacker handling moist, sticky material which builds up on the rollers.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Leach tanks handling hot slurry, agitators driven by Falk gear reducing units.


V.A. Wemco classifier, part of wet grinding system, lower bearing submerged in hot sludge.

Here's a report of our own experience with lithium-base grease under extreme industrial service conditions. Approximately 95% of the grease used in the plant of American Lithium Chemicals, Inc., our subsidiary at San Antonio, Texas, is lithium-base, one-type grease. In fourteen months operation we have not been able to trace a single cause for bearing failure to the lubricant used. The on-the-spot photos above give graphic evidence of the rugged bearing service requirements in this plant where lithium ores are processed into high-grade lithium hydroxide, itself an important ingredient in lithium-base grease. Performance like this is why grease chemists, manufacturers, marketers and users all attest to the superiority of lithium-base...the *one* grease in place of *many* for efficient and economical operation.

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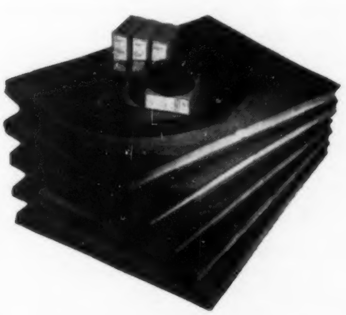
News About NLGI

Complete Filmed Volumes

WITH the completion of photography on all bound volumes of the *NLGI Spokesman,* the entire set of 21 books may now be purchased on microfilm from University Microfilms, Ann Arbor, Michigan. Before, only books XIV through XXI were on film. Volumes are contained on rolls of film (above) measuring three and three-quarters inches in circumference, for easy and convenient use and storage.



Veresit, fabrica de productos, quimicos, of Buenos Aires, Argentina have affiliated with the Institute in the capacity of an NLGI Technical member. Dr. Alexander Erdely serves as both Company and Technical Representative for this new member, the seventh to join the Institute since the first of the year.

Raffineries Imperator, new overseas NLGI Active member, has named Constantin Karpitsky in both capacities as Company and Technical Representative to the Institute.

NLGI Wheel Bearing Manual Gets Widespread Publicity

President Cubiccioti Featured in Marketing Magazine

NLGI received recognition in two trade publications during the month of April . . . features were run on the Institutute's wheel bearing manual and on R. Cubicciotti. The entire "Recommended Practices for Lubricating Front Wheel Bearings" was reproduced in a two-and-a-half page spread of the April 16 issue of *The Gasoline Retailer,* offering the Institute widespread publicity and distributing further the proper method of lubricating wheel bearings as recommended by NLGI for many years now.

Printers' Ink, a marketing magazine, featured R. Cubicciotti in a regular section of the publication entitled "The Sale I Never Forgot." The April 25 issue recounted a lubrication problem of the 30's that Mr. Cubicciotti solved by selling quality, not price, to boost sales.

SERVICE AIDS

Send Orders to: National Lubricating Grease Institute, 4638 Nichols Parkway, Kansas City, Mo.

NLGI MOVIE — "Grease, the Magic Film," a 16-mm sound movie in color running about 25 minutes, now released. First print $600, second print $400, third and subsequent orders $200 each (non members add $100 to each price bracket).

VOLUME XX — Bound volume of the NLGI SPOKESMAN from April, 1956 through March, 1957. An excellent reference source, sturdily bound in a handsome green cover . . . $7.00 (NLGI member price) and $10.00 (non-member) plus postage.

VOLUME XXI—Bound volume of the NLGI SPOKESMAN from April, 1957 through March, 1958. Contains 34 articles and features dealing with lubricating greases and gear lubricants . . . $7.00 (NLGI member price) and $10.00 (non-member) plus postage.

BONER'S BOOK—Manufacture and Application of Lubricating Greases, by C. J. Boner. This giant, 982-page book with 23 chapters dealing with every phase of lubricating greases is a must for everyone who uses, manufactures or sells grease lubricants. A great deal of practical value. $18.50, prepaid.

NLGI PRESIDENT'S PAGE

By R. CUBICCIOTTI, *President*

Product Research, a Consumer-Inspired Benefit

I wonder how many members of the National Lubricating Grease Institute ever stop to think how important the role of the consumer has been in the new product developments and improvements that have made our industry what it is today.

It is perfectly natural, in our industry as well as others, for one company to seek to make a product that is better than the next company. Yet there remains an additional major point that deserves important consideration: We should take great pride in the fact that the constant research being conducted by members of the Institute has resulted in the development of better and more efficient types of lubricating greases which, in turn, have been of great benefit to the nation as a whole.

Because the logical outcome of these constant improvements is that any further refinements tend to be of a less dramatic nature than the introduction of, say, any new or startling innovations, we must constantly be on guard to maintain a proper perspective. We must continually remind ourselves that each little step forward that we take may have as much significance in the long run as the big step.

It is in these little steps that we have succeeded in achieving a sense of co-operative effort throughout the lubricating grease industry. This is due mainly to the fact that such steps have always been the result of conscious efforts to help the consumer. And in striving to help the consumer the members of our industry have actually been of service to each other.

The problem of multi-purpose grease is an illustration in point. There are products on the market that are specified for multi-purpose application. However, manufacturers of bearings still specify any number of different types of grease for their product. The fact of the matter is that bearing manufacturers, as revealed in the recent American Lithium Institute survey, do not find most of the multipurpose lubricating greases now on the market to be entirely satisfactory.

It also is a fact that our industry has for some time been trying to find the ideal multi-purpose grease. While the producer who finally evolves such a product will have achieved a major advance in the evolution of lubricating grease, the achievement will not necessarily be considered a "revolutionary" development. It will most likely be regarded by all of us as the logical conclusion of all the methodical research conducted over the years by many companies that have been spurred on by the realization of the consumer's needs.

Many members of the National Lubricating Grease Institute will have had a share in the ultimate outcome. By our common efforts we will have helped the consumer and ultimately the nation. ■

"Ed, what did you do about that contamination problem in the drums on the new light products line?"

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nlgi spokesman

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IN THIS ISSUE

THE COVER

WITH distribution of "Grease—the Magic Film" now world wide in scope after its premiere six months ago, a growing audience of viewers like that shown on our cover are seeing and hearing the story of lubricating grease . . . the many kinds of grease and how these lubricants stand up under every sort of abuse. In part subsidized by the National Lubricating Grease Institute, "Grease—the Magic Film" tells in 26 minutes the research and application, the need and the employment of the industry's products. For further information about the picture, turn to the six-month resume beginning on page 119.

13,500 POUNDS of GREASE

every 8 hours!

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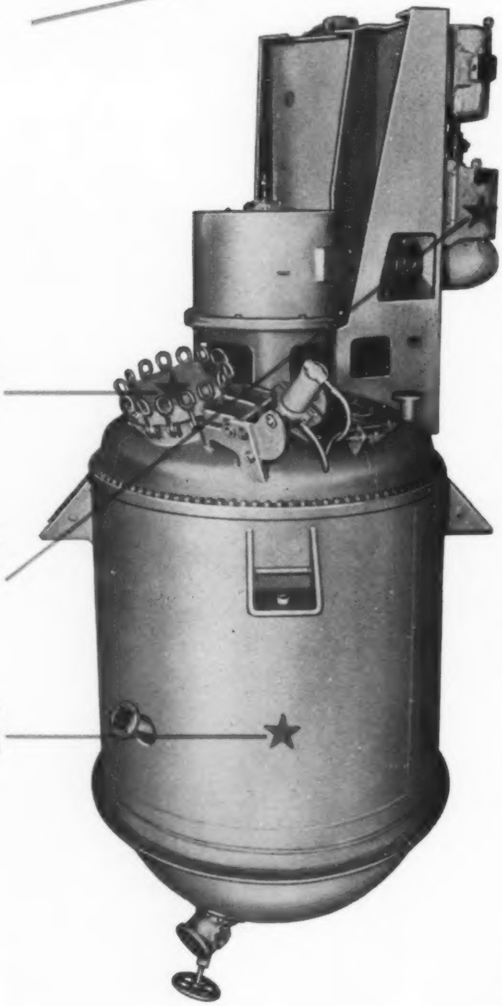

This is a stainless steel grease mixer recently completed for one of the major oil corporation's grease plants in Texas. All parts in contact with the mix are made of clad or solid type 304 stainless steel.

Note particularly the new vertical drive arrangement that permits maximum aisle clearance around the unit . . . also the newly-designed hydraulic-operated manhole with special built-in safety features. These are typical of Struthers Wells leadership in modern, efficient grease making equipment.

Are you searching for improved efficiency in your mixing operations? Struthers Wells will help you find it quickly with equipment designed to meet your specific requirements.

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Crankshafts . . . Pressure Vessels . . . Hydraulic Cylinders . . . Shafting . . . Straightening and Back-up Rolls

Future Meetings

JUNE, 1958

8-13 API Division of Production, Midyear Committee Conference, Hollywood Beach Hotel, Hollywood, Fla.

8-13 SAE Summer Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

22-28 ASTM 61st Annual Meeting, Hotel Statler, Boston, Mass.

AUGUST, 1958

10-15 National Congress of Petroleum Retailers, Inc., 12th Annual Session, McAllister Hotel, Miami, Florida.

SEPTEMBER, 1958

8 NLGI Board of Directors meeting, New York City, location to be announced.

10-12 National Petroleum Association, 56th Annual Convention, Traymore Hotel, Atlantic City, N. J.

24-25 Oil Petroleum Marketers Association Fall Conference and Golf Tournament, Dayton Biltmore Hotel and Walnut Grove Country Club, Dayton, Ohio.

28-30 IOCA Eleventh Annual Meeting, Palmer House Hotel, Chicago, Ill.

OCTOBER, 1958

13-15 ASLE-ASME Joint Lubrication Conference, Hotel Statler, Los Angeles, Calif.

20-22 SAE National Transportation Meeting, Lord Baltimore Hotel, Baltimore, Md.

22-24 SAE National Diesel Engine Meeting, Lord Baltimore Hotel, Baltimore, Md.

27-29 NLGI Annual Meeting, Edgewater Beach Hotel, Chicago, Ill.

NOVEMBER, 1958

5-6 SAE National Fuels and Lubricants Meeting, The Mayo, Tulsa, Okla.

10-13 API, 38th Annual Meeting.

30-Dec. 5 ASME, Annual Meeting.

FEBRUARY, 1959

2-6 ASTM National Meeting, William Penn Hotel, Pittsburgh, Pa.

***MARCH, 1959**

3-5 SAE Passenger Car, Body, and Materials Meeting, Sheraton-Cadillac, Detroit, Mich.

APRIL, 1959

21-23 ASLE Annual Meeting and Exhibit, Hotel Statler, Buffalo, New York.

*Tentative.

JUNE, 1959

14-19 SAE Summer Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

OCTOBER, 1959

11-16 ASTM National Meeting, Sheraton-Palace Hotel, San Francisco, Calif.

19-21 ASLE-ASME Joint Lubrication Conference, Sheraton-McAlpin Hotel, New York, N. Y.

26-28 NLGI Annual Meeting, New Orleans, La.

FEBRUARY, 1960

1-5 ASTM National Meeting, Hotel Sherman, Chicago, Ill.

APRIL, 1960

19-21 ASLE Annual Meeting and Exhibit, Netherland-Hilton Hotel, Cincinnati, Ohio.

SIX MONTH RESUME . . .

a report on the nlgi movie "grease—the magic film"

SOME SIX MONTHS AGO, at the NLGI Annual Meeting in Chicago, the Institute's new moving picture was premiered to the membership. This 26-minute color picture in 16mm sound was produced by and for the organization, in an effort to offer a service that was at once informative and educational for whatever publics the member firms chose to show the movie to.

Not only did the picture receive acclaim at Chicago but members began purchasing copies and putting "Grease—the Magic Film" to work. To date more than 60 copies have been distributed in this country and abroad, with viewings scheduled to a number of various uses. Thanks to the medium of this motion picture a growing awareness of lubricating grease and the jobs it does is being imparted to the audiences . . . a work which will grow with succeeding showings.

Members and friends of NLGI wishing to preview a copy of the movie may still do so without obligation, by merely writing the national office. Cost of the prints is borne in part by the Institute and member firms receiving a substantial discount. (For details see page 111.) Copies can be obtained with company indentification on the leader at a slight extra cost, while second and third print prices are reduced for a greater saving.

For an excellent method to tell a complex story to a large group in a short time, why not try a copy of "Grease—the Magic Film."

LEFT—In a scene from the moving picture, this shot shows a lubricating grease application in an ice cream storage room where the lubricant must function at sub-zero temperatures . . . heat and washing actions are just a few of the other interesting examples given in "Grease—the Magic Film."

FLOW PROPERTIES OF LUBRICATING OILS UNDER PRESSURE

By:

SANG JOON HAHN —NLGI Fellowship Student, University of Utah

DR. HENRY EYRING —Dean of Graduate School, University of Utah

IZUMI HIGUCHI —Professor of Chemistry, Tohku University, Sendai, Japan

DR. TAIKYUE REE —Research Professor of Chemistry, University of Utah

Presented at the NLGI 25th annual meeting in Chicago, October, 1957

DISCUSSION of rheological research . . . E. W. Adams (l), technical subcommittee chairman for the Institute's research program . . S. J. Hahn, the NLGI fellow . . . and T. G. Roehner, chairman of the Grease Institute's Technical Committee.

Progress in Research

"THAT IF INDUSTRY progress is to be assured, an increasing pool of scientific knowledge . . . must be created." With these words Howard Cooper, president of NLGI in 1951, announced the formation of a new Institute service—the research fellowship. NLGI's subsequent annual grants have acted as insurance for the above-mentioned progress, with reports in this journal disseminating the findings each year. Three of the authors of this report are familiar to NLGI SPOKESMAN *readers from last year's article . . . Messrs. Hahn, Ree and Eyring. They were joined by Mr. Higuchi, who has since returned to Japan. As announced in March, another award was made to the University of Utah for the NLGI fellowship, for the academic year of 1958-59.*

Abstract

The flow properties of lubricating oils under pressure are described in terms of two kinds of flow units: Newtonian and non-Newtonian units. The increase in viscosity and non-Newtonian character with pressure are explained by the following two assumptions: (1) The transition, Newtonian unit ⟶ non-Newtonian unit, is induced at high pressures. (2) The relaxation time increases with pressure. By introducing the above ideas into the Ree-Eyring theory of non-Newtonian flow, a new flow equation is derived, which is successfully applied to the flow of sperm oil, SAE 30 motor oil, lard oil, castor oil, naphthenic petroleum, paraffinic petroleum, and synthetic lubricant [di-(2-ethyl hexyl) sebacate] under pressure. The effect of pressure on grease is considered, and the theory that the network of soap fibers is destroyed under pressure is proposed.

Introduction

Generally, grease is under pressure when it is to be used. Thus, the study for flow properties of lubricating oils under pressure has a great significance in practice.

It is well known that the viscosity of liquids increases under pressure.[1, 2] It was also found that the flow property of liquids, specifically of lubricating oils, becomes non-Newtonian when high pressure was applied.[3]

Here we study the flow properties of lubricating oils under pressure using the Ree-Eyring theory of non-Newtonian flow[4, 5] because they are one of the constituents of grease.

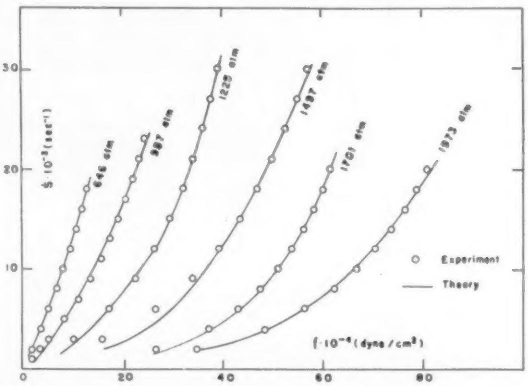

FIG. 1—flow curves of sperm oil at 0°C, various pressures.

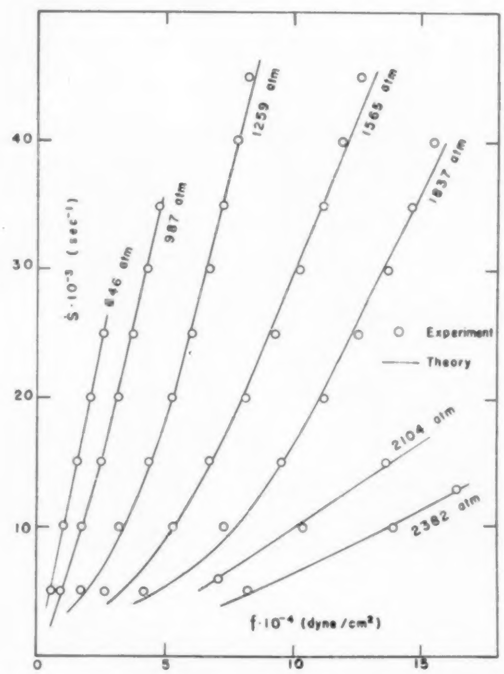

FIG. 2—flow curves of sperm oil at 20°C, various pressures.

Theory

According to the Ree-Eyring theory,[4] stress, f, is given as a function of sheer rate, ṡ, by

$$f = \sum_{i=1}^{n} \frac{X_i}{\alpha_i} \sinh^{-1} B_i \dot{s} \qquad (1)$$

where

$$\alpha_i = (\lambda\lambda_2\lambda_3)_i / 2kT \qquad (2)$$

$$\beta_i = 1/\left[\left(\frac{\quad}{\lambda_1}\right) 2k'\right]_i \qquad (3)$$

In equation (1), X_i is the fraction of area occupied by the ith kind of flow unit, β_i is the quantity which is proportional to the relaxation time of the ith kind, k' is the specific rate constant, and the λ's are the molecular parameters in Eyring's theory of viscosity.[6, 7]

If there are two kinds of units (Newtonian and non-Newtonian) instead of n kinds, equation (1) is written as

$$f = \frac{X_1\beta_1}{\alpha_1}\dot{s} + \frac{X_2}{\alpha_2}\sinh^{-1}\beta_2\dot{s} \qquad (4)$$

By assuming that

$$X_1\beta_1/\alpha_1 << X_2\beta_2/\alpha_2 \qquad (5)$$

equation (4) is approximated by the relation

$$f = \frac{X_2}{\alpha_2}\sinh^{-1}\beta_2\dot{s} \qquad (6)$$

The inequality (5) is due to the fact that $\beta_1/\alpha_1 <<< \beta_2/\alpha_2$, while $X_1 >> X_2$.

It is often found that non-Newtonian units transform to Newtonian units. For example, thixotropy is explained by the transition:[8]

$$\text{Newtonian} \underset{\text{Stress Release}}{\overset{\text{Stress}}{\rightleftarrows}} \text{non-Newtonian}$$

We thus assume that the transition, Newtonian →

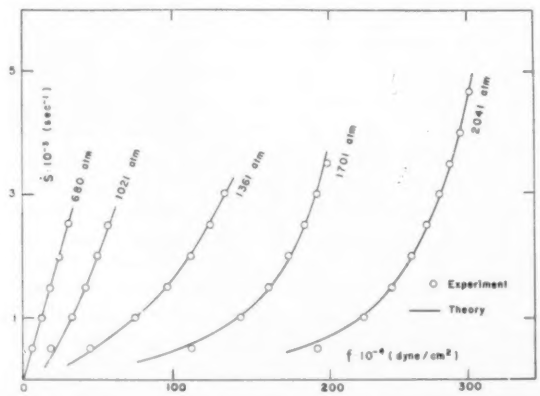

FIG. 3—flow curves of SAE 30 motor oil (partially worked) at 0°C under various pressures, as pictured in this diagram.

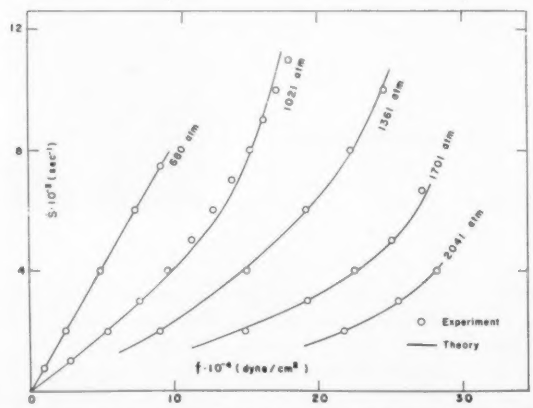

FIG. 4—flow curves of SAE 30 motor oil (partially worked) at 20°C under various pressures, as pictured in this diagram.

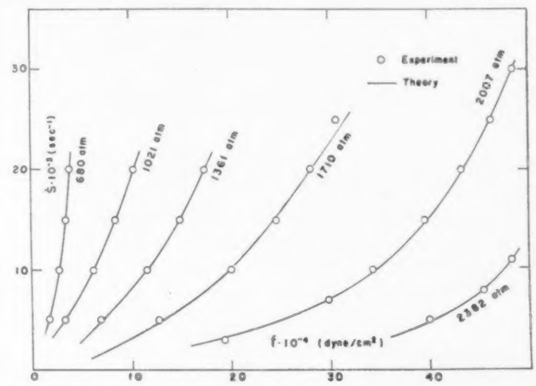

FIG. 5—flow curves of lard oil at 20°C, various pressures.

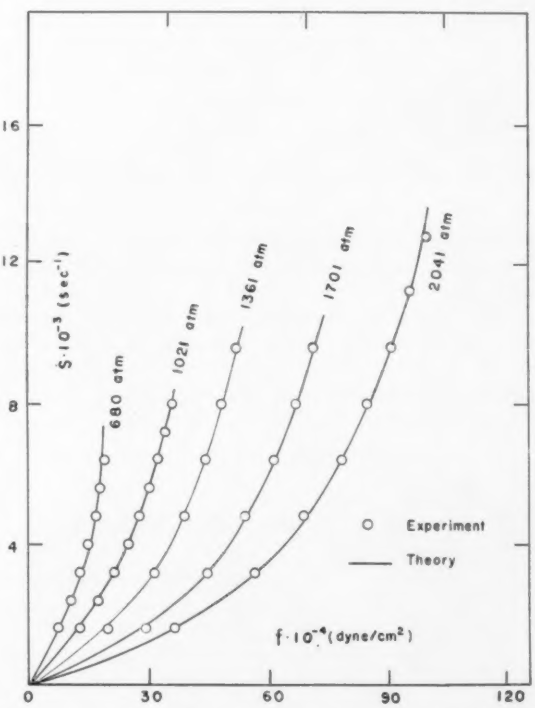

FIG. 6—flow curves of castor oil at 20°C, various pressures.

non-Newtonian, is brought about by high pressures whereas the reverse occurs by the release of pressures. The concentration of non-Newtonian units, C_2, at the transition equilibrium under pressure, p, is given by

$$(1\text{-}C_2)/C_2 = \exp\,(\Delta F/RT) \qquad (7)$$

where ΔF is the change in the free energy accompanying the transition. If it is assumed that the molecular volume of the Newtonian unit is approximately equal to that of the non-Newtonian unit, the following is true:[9]

$$C_1 = X_1 \text{ and } C_2 = X_2$$

By assuming $C_1 >> C_2$, equation (7) is transformed to

$$\begin{aligned} X_2 &\simeq \exp\,(-\Delta F/RT) \\ &= K_0 \exp\,(-p\Delta V/RT) \qquad (8) \end{aligned}$$

Here, $\Delta F = \Delta F_0 + p\Delta V$, K_0 is the equilibrium constant at $p = 0$, and ΔV is the volume change accompanying the transition.

The activation free energy, ΔF^*, for flow increases with pressure,[7, 10, 11], i.e.,

$$\Delta F^* = \Delta F_0^* + p\Delta V^* \qquad (9)$$

In equation (9), ΔF_0^* is the activation free energy at $p = 0$, and ΔV^* is the change of volume in the activation. By using (9) and (3), β_2 is written as

$$\beta_2 = \left[\frac{\lambda}{\lambda_1}\ 2\ \frac{kT}{h}\right]^{-1} \exp\,(\Delta F^*/RT) \qquad (10a)$$

$$= \beta_{20} \exp\,(p\Delta V^*/RT) \qquad (10b)$$

where,

$$\beta_{20} = \left[\frac{\lambda}{\lambda_1}\ 2\ \frac{kT}{h}\right]^{-1} \exp\,(\Delta F_0^*/RT) \qquad (11)$$

SANG JOON HAHN *received the National Lubricating Grease Institute fellowship for 1956-1957 and is studying toward a doctorate degree in physical chemistry at the University of Utah. Sang is working under the supervision of Dr. Henry Eyring and is principally concerned with the mechanisms of liquid flow. A graduate of the Seoul National University in 1948, Hahn instructed in chemistry at the Ewha University in Korea from 1948 to 1955, then began graduate work at Utah University.*

DR. HENRY EYRING *has been dean of the graduate school, University of Utah since 1946. He is also associate editor of "Textile Research Journal." From 1944 to 1946 he was research director of the Textile Foundation, worked with the Office Science Research & Development, U. S. Navy in 1944 and received the Alumni Achievement Award from Arizona University in 1947. Dr. Eyring received the degrees of B. S. and M. S. from Arizona University, Ph. D. in chemistry from California, and Honorary Science Degree from Utah in 1952, Northwestern, 1953 and Princeton in 1956. He is a member of the National Academy, Soc. Rheol., winning the Bingham Medal 1949, Chem. Soc., winning the Nichols Medal in 1951, and Philos. Soc.*

DR. TAIKYUE REE *has been a research professor in chemistry at the University of Utah since 1949. He received B. S. and Sc. D. degrees in chemistry from Kyoto Imperial University, Japan in 1931. He became a professor of chemistry there following graduation and achieved professorship in 1943. In 1945 he was named dean and professor of the college of liberal arts and sciences at the Seoul National University, Korea, where he remained until taking his present position at the University of Utah. Dr. Ree has devoted his time to the study of chemical kinetics, catalysis, reactivity of organic substances, rheology, quantum chemistry.*

About the Authors

I. HIGUCHI *graduated from Tohoku university, Sendai, Japan, in 1933. He received his Sc.D. degree in chemistry from Tohoku university in 1941 and was assistant professor of chemistry at that university from 1942-1954. From 1954-1956 he was research associate at the University of Utah working on a research grant from the California Research corporation. His work on the paper "Flow Properties of Lubricating Oils Under Pressure" was done during his stay at the University of Utah. A well known chemist in Japan, he has been professor of chemistry at Tohoku university since 1956.*

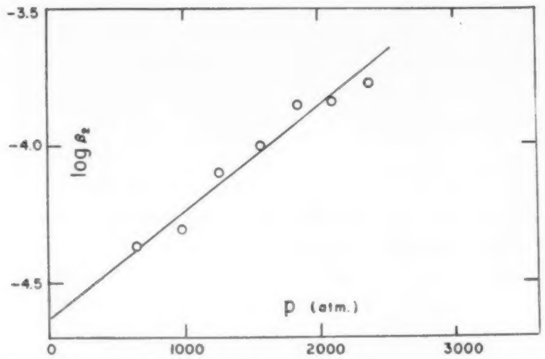

FIG. 7—logarithm of B_2 vs. pressure for sperm oil at 20°C.

The substitution of (8) and (10b) into (6) yields

$$f = \left[\frac{K_0}{\alpha_2}\, e^{\frac{-p\Delta V}{RT}}\right] \sinh^{-1} \left[\beta_{20}\, e^{\frac{p\Delta V^{\ddagger}}{RT}}\, \dot{s}\right] \qquad (12)$$

This is the equation of flow under pressure.

Results

Applications to Flow Curves

By applying equation (12) or (6) to the flow curves of sperm oil,[3] SAE 30 motor oil,[3] lard oil,[3] and castor oil,[3] we obtained the factors, X_2/α_2 and β_2. Here β_2 is given by (10), and X_2/α_2 is the coefficient of the hyperbolic sine function of equation (12), i.e.,

$$\frac{X_2}{\alpha_2} = [\exp(-\Delta F/RT)]/\alpha_2 \qquad (13a)$$

$$= \frac{K_0}{\alpha_2} \exp(-p\Delta V/RT) \qquad (13b)$$

The factors, X_2/α_2 and β_2, are summarized in Table I. The full curves in Figures 1 to 6 are calculated from (6) (or 12) by using these factors. One sees that equation (6) (or 12) expresses the experiments very well. As shown in Figures 1 to 6, the flow curves at low pressure are Newtonian. Thus, equation (12) becomes

$$f = \frac{X_2}{\alpha_2}\beta_2 \dot{s} = \frac{K_0}{\alpha_2}\beta_{20} \dot{s} \exp[p(-\Delta V + \Delta V^{\ddagger})/RT] \qquad (14)$$

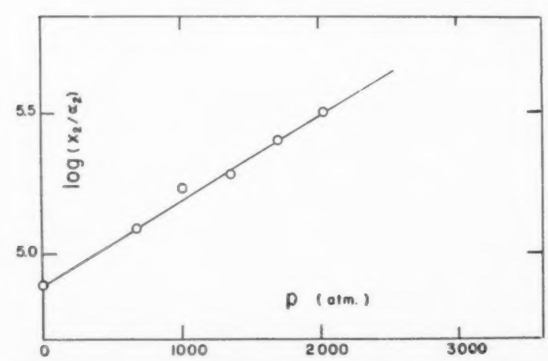

FIG. 8—logarithm of (X_2/α_2) vs. pressure, castor oil at 20°C.

TABLE I

Flow Parameters Under Pressure

A. Sperm Oil (*Partially Worked*)

Temperature 0°C
$\Delta F_0^{\ddagger} = 10.30$ kcal
$\Delta V^{\ddagger} = 51.4$ cc
$\Delta V = 13.4$ cc

p (atm)	$X_2/\alpha_2 \cdot 10^{-6}$ (dyne/cm²)	$\beta_2 \cdot 10^4$ (Sec.)
0	0.0870	0.153
646	0.102	0.910
987	0.135	1.30
1225	0.145	2.50
1497	0.197	3.00
1701	0.155	13.5
1973	0.204	13.2

Temperature 20°C
$\Delta F_0^{\ddagger} = 11.34$ kcal
$\Delta V^{\ddagger} = 24.5$ cc
$\Delta V = 17.8$ cc

p (atm)	$X_2/\alpha_2 \cdot 10^{-5}$ (dyne/cm²)	$\beta_2 \cdot 10^5$ (Sec.)
0	0.244	2.32
646	0.310	3.43
987	0.360	5.00
1259	0.391	8.00
1565	0.565	10.0
1837	0.641	14.0
2109	0.909	16.0
2382	1.07	17.0

B. SAE 30 Motor Oil (*Partially Worked*)

Temperature 0°C
$\Delta F_0^{\ddagger} = 10.60$ kcal
$\Delta V^{\ddagger} = 83.9$ cc
$\Delta V = 5.00$ cc

p (atm)	$X_2/\alpha_2 \cdot 10^{-6}$ (dyne/cm²)	$\beta_2 \cdot 10^3$ (Sec.)
0	0.420	0.279
680	0.383	0.316
1021	0.299	1.30
1361	0.591	1.65
1701	0.478	10.5
2041	0.464	71.0

Temperature 20°C
$\Delta F_0^{\ddagger} = 11.42$ kcal
$\Delta V^{\ddagger} = 51.3$ cc
$\Delta V = 8.90$ cc

p (atm)	$X_2/\alpha_2 \cdot 10^{-5}$ (dyne/cm²)	$\beta_2 \cdot 10^4$ (Sec.)
0	1.04	0.269
680	1.04	1.17
1021	0.945	3.00
1361	1.11	4.50
1701	1.20	8.00
2041	0.943	25.0

C. Lard Oil

Temperature 20°C
$\Delta V^{\ddagger} = 50.7$ cc
$\Delta V = 7.60$ cc

p (atm)	$X_2/\alpha_2 \cdot 10^{-5}$ (dyne/cm²)	$\beta_2 \cdot 10^4$ (Sec.)
0	0.640	0.0891
680	0.869	0.355
1021	0.765	0.900
1361	0.932	1.60
1701	1.22	2.50
2007	1.30	7.00
2382	1.19	28.0

D. Castor Oil (*Partially Worked*)

Temperature 20°C
$\Delta V^{\ddagger} = 15.6$ cc
$\Delta V = 17.4$ cc

p (atm)	$X_2/\alpha_2 \cdot 10^{-6}$ (dyne/cm²)	$\beta_2 \cdot 10^4$ (Sec.)
0	0.101	2.10
680	0.124	3.00
1021	0.169	4.00
1361	0.192	6.00
1701	0.251	7.00
2041	0.318	7.00

Since the factors, X_2/α_2 and β_2, are not separable at low pressures, they are obtained by extrapolating the corresponding values obtained at high pressures. The values of X_2/α_2 and β_2 at zero pressure in Table I are obtained by this procedure.

By plotting $\ln(X_2/\alpha_2)$ versus p, one obtains a straight line (cf. equation 13b), α_2 being assumed to be pressure independent. From the slope of the straight line, ΔV is calculated. Similarly, $\Delta V^{\ddagger}$ is determined from the plot of $\ln \beta_2$ versus p (cf. equation 10b). An example for each of the two plots are shown in Figures 7 and 8. The values of ΔV and $\Delta V^{\ddagger}$ thus obtained are shown in Table I.

By extrapolating β_2's obtained at various pressures to $p = o$, the quantity, β_{20}, is evaluated. Then, from the value of β_{20}, $\Delta F_0^{\ddagger}$ is calculated by using equation (11) and by assuming $\lambda \simeq \lambda_1$. The values of $\Delta F_0^{\ddagger}$ in Table I were obtained by this procedure.

From equations (10a) and (13a), the following equations are obtained, respectively:

$$\Delta H^{\ddagger} = 4.575 \left(\frac{1}{T_a} - \frac{1}{T_b}\right)^{-1} \log \frac{(\beta_2)_a}{(\beta_2)_b} \qquad (15)$$

and

$$\Delta H = -4.575 \left(\frac{1}{T_a} - \frac{1}{T_b}\right)^{-1} \log \left[(X_2/\alpha_2)_a/(X_2/\alpha_2)_b\right] \qquad (16)$$

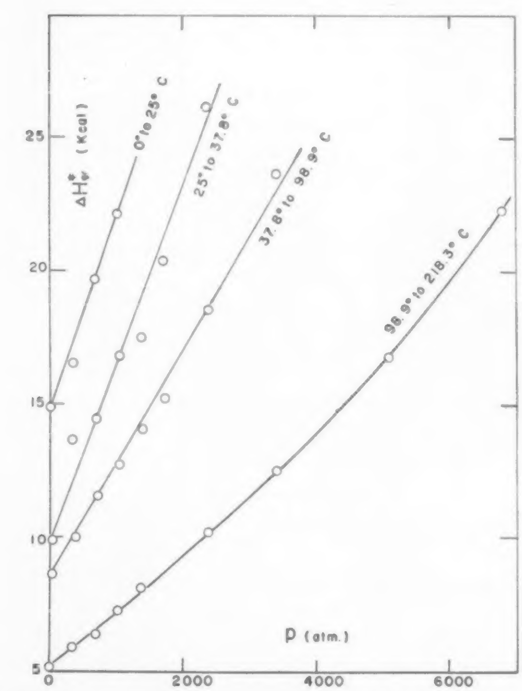

FIG. 9—showing gross activation heat ($\Delta H_{gr}^{\pm}$) versus pressure for naphthenic petroleum oil at various temperatures.

Here T_a and T_b are two given temperatures, and the factors obtained at these temperatures carry the attached subscripts a and b. In deriving equation (16), α_2 is assumed to be independent of temperature in agreement with Ree and Eyring.[4, 5] The values of $\Delta H^{\ddagger}$ and ΔH in Table II were calculated from (15) and (16) using the values of β_2 and X_2/α_2 in Table I. It is worthy of note that ΔH is consistent irrespective of pressure whereas $\Delta H^{\ddagger}$ increases with pressure in a remarkable manner.

TABLE II

The Value of ΔH, $\Delta H^{\ddagger}$, and $\Delta H^{\ddagger}_{gr}$

	Sperm Oil (0°–20°C)		
p (atm)	ΔH kcal	$\Delta H^{\ddagger}$ kcal	$\Delta H^{\ddagger}_{gr}$ kcal
0	−10.1	− 3.32	6.78
646	− 9.85	3.59	13.4
987	− 9.62	5.95	15.6
1259	− 9.27	10.4	19.6
1565	− 8.82	13.8	22.6
1837	− 8.25	16.7	24.9
2109	− 7.42	19.9	27.3

	SAE 30 Motor Oil (0°–20°C)		
p (atm)	ΔH kcal	$\Delta H^{\ddagger}$ kcal	$\Delta H^{\ddagger}_{gr}$ kcal
0	−12.2	0.293	12.5
680	−12.2	8.83	21.0
1021	−12.2	13.6	25.8
1361	−12.2	17.8	30.0
1701	−12.2	22.1	34.3
2041	−12.4	26.4	38.8

Applications to the Curves of ln η versus p

Recently, Bradbury, Mark and Klunschmidt[12] measured Newtonian viscosities of naphthenic petroleum, paraffinic petroleum, and synthetic lubricant [di-

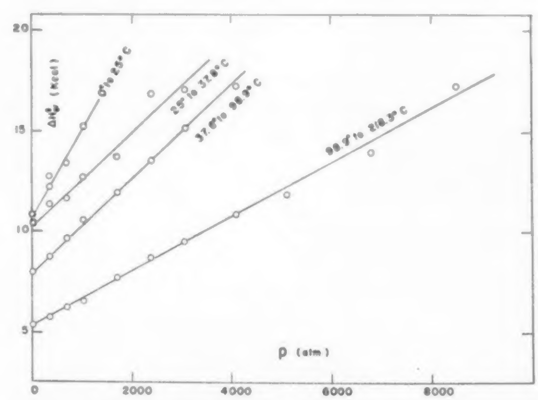

FIG. 10—with the gross activation heat ($\Delta H_{gr}^{\pm}$) versus pressure for paraffinic petroleum oil at various temperatures.

(2-ethyl hexyl) sebacate] under pressure. From their curves of ln η versus p we calculate $\Delta H^{\ddagger}_{gr}$ (the gross activation heat) using the following formula:

$$\Delta H^{\ddagger}_{gr} = 4.575\,\left(\frac{1}{T_a} - \frac{1}{T_b}\right)^{-1} \log\,(\eta_a/\eta_b) \qquad (17)$$

The results are graphically shown in Figures 9 to 11.

Equation (17) is often used for calculating activation heats for flow. The quantity, $\Delta H^{\ddagger}_{gr}$, however, is not equal to $\Delta H^{\ddagger}$ calculated from (15). The reason is as follows:

The Newtonian viscosity is given by $(X_2/\alpha_2)\beta_2$ from equation (14). The substitution of $(X_2/\alpha_2)\beta_2$ to η of (17) yields

$$\begin{aligned}\Delta H^{\ddagger}_{gr} &= 4.575\,\left(\frac{1}{T_a} - \frac{1}{T_b}\right)^{-1}\left[\log\frac{(X_2/\alpha_2)_a}{(X_2/\alpha_2)_b} + \log\frac{(\beta_2)_b}{(\beta_2)_a}\right] \\ &= -\Delta H + \Delta H^{\ddagger} \qquad (18)\end{aligned}$$

Since ΔH is a negative quantity, $\Delta H^{\ddagger}_{gr}$ is equal to the sum of $|\Delta H| + \Delta H^{\ddagger}$. The quantity, $\Delta H^{\ddagger}_{gr}$ in Table II is calculated from equation (18).

As shown in Figures 9, 10, and 11, $\Delta H^{\ddagger}_{gr}$ increases with pressure linearly to a good approximation. This increase, however, is only due to $\Delta H^{\ddagger}$, since ΔH is independent of pressure. A linear dependence of $\Delta H^{\ddagger}_{gr}$ on p is also found for sperm oil and SAE 30 Motor oil.

Activation Entropy

In Figure 12, the values of $\Delta H^{\ddagger}$ for sperm oil and for SAE 30 motor oil given in Table II are plotted against p. The straight lines of $\Delta F^{\ddagger}$ versus p are calculated from equation (9) using the values of $\Delta F^{\ddagger}_0$ and $\Delta V^{\ddagger}$ given in Table I. One sees that the increase of $\Delta H^{\ddagger}$ with pressure is remarkable while that of $\Delta F^{\ddagger}$ is much less. That is, the compensation principle[13] holds here, but not completely.

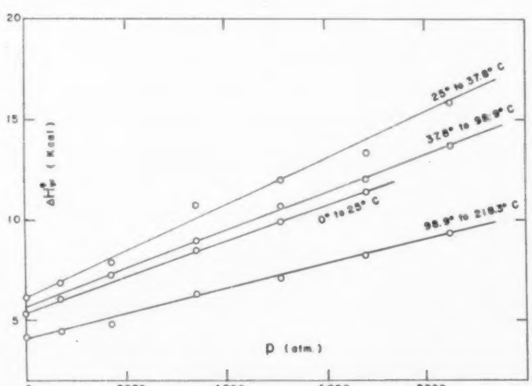

FIG. 11—showing gross activation heat ($\Delta H_{gr}\pm$) versus pressure for synthetic lubricant [di-(2-ethyl hexyl) sebacate] at various temperatures.

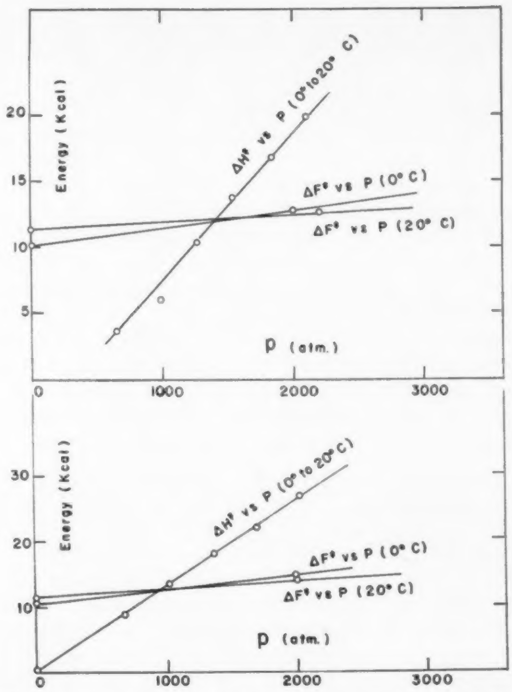

FIG. 12—two separate plots of $\Delta H\pm$ vs. pressure and $\Delta F\pm$ vs. pressure for sperm oil (above) and SAE 30 motor oil.

From the values of $\Delta F^{\ddagger}$ and $\Delta H^{\ddagger}$ at a given p, the activation entropy, $\Delta S^{\ddagger}$, is calculated. The results are summarized in Table III. The values of $\Delta S^{\ddagger}$ are negative at low pressures being positive at high pressures. Negative activation entropies are very often found in plastic flow.[14, 15, 16, 17]

Table III

The Value of $\Delta S^{\ddagger}$ (e.u.)

p (atm)	Sperm Oil (20°C)	SAE 30 Motor Oil (20°C)
800	−22.5	− 5.80
1000	−15.4	2.39
1200	− 8.19	11.6
1400	− 1.37	18.4
1600	− 5.80	25.3
1800	13.3	34.1
2000	20.5	41.3

Discussion

Homogeneity Versus Heterogeneity of Flow Units

One might consider that the flow curves under pressure would be described by a single kind of flow unit without using the idea of the structure changes, since the flow equation (6) (or 12) involves only type 2 units. Such a treatment of lubricating oils as a homogeneous flow system, however, has the serious difficulties mentioned below.

From the assumption that the system is homogeneous, equation (6) is written as

$$f = \frac{1}{\alpha} \sinh^{-1} \beta \dot{s} \qquad (19)$$

By applying (19) to the flow curves, it is found that both the factors, $1/\alpha$ and β, increase with pressure as mentioned previously. From the increase of $1/\alpha$, the compressibility of the shear volume, $\lambda\lambda_2\lambda_3$, is calculated. The result is that the compressibility is as large as ten times that of ordinary liquids. Also the expansion coefficient of $\lambda\lambda_2\lambda_3$ at a constant pressure is calculated from the data in Table I. The value of the calculated expansion coefficient is larger by a factor of one hundred than the observed value. Evidently, these results are unreasonable. Thus, we must introduce the heterogeneity idea, and assume the transition of Newtonian units into non-Newtonian units under pressure.

According to our theory, X_2 increases with pressure (cf. equation (8), where $\triangle V$ is a negative quantity). Thus, the increase of X_2/α_2 in equation (6) with pressure is due to X_2 rather than α_2, which we take to be independent of pressure here. There are good reasons for believing that the pressure dependence of α_2 is very small. Newtonian viscosity for simple liquids is given by β/α (cf. equation (19). Comparing this expression with the Maxwell relation, $\eta = G\tau$ (G = shear modulus, τ = relaxation time), one finds that $1/\alpha$ should be proportional to the shear modulus G, since β is proportional to τ. Generally, the change of G with p is very small.[1] Thus the large change of X_2/α_2 with p cannot be ascribed to $1/\alpha_2$. There is another reason for supposing that the dependence of α on pressure is very small. According to the hole theory of Hirai, Ree, and Eyring,[11] the following approximation is justified: $\lambda \simeq (V_h)^{1/3}$ and $\lambda_1 = \lambda_2 = \lambda_3 \simeq V_0^{1/3}$. Thus we have $\lambda\lambda_2\lambda_3 = V_h^{1/3} V_0^{2/3}$, where V_h is the volume of a hole and V_0 is the volume of a molecule in a solid state. The quantities, V_h and V_0, are considered to be nearly independent of pressure. Consequently, α is treated as approximately independent of pressure.

Transition Between Newtonian and Non-Newtonian Units

It was experimentally found that under pressure, lubricating oils become thixotropic, and solidify even at temperatures above the melting point.[2] This fact indicates that a molecular association is induced under high pressure. Thus, we assume that a Newtonian unit transforms to a non-Newtonian one by associating with neighboring molecules. Since $\triangle H$ for the transition is about 10 kcals, the reaction may involve a hydrogen bond formation.

Grease Under Pressure

The viscosity of grease decreases with pressure and increases at pressures higher than 10^3 atm.[2] Water shows a similar pressure minimum. As one would expect from the viscosity of water, the peculiar character of grease viscosity is due to the structural change of grease under pressure.

Grease contains soap and lubricating oil. According to recent studies,[8, 18, 19] a grease forms a three dimensional network of soap fibers with the lubricating oil trapped between fibers. The network yields under an applied stress, and thus the grease flows.[8] The network is considered to be destroyed under pressure with an accompanying decrease in viscosity. The increase of viscosity at high pressures is a common property of lubricating oils as discussed above. We plan later to treat the viscosity change of greases due to hydrostatic pressure as a structure change, extending the method developed here for lubricating oils.

Acknowledgments

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The Studebaker-Packard Twin Traction Differential —Its Problems and Limitations

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Presented at the February, 1958 meeting of the API Lubrication Committee, in Detroit.

THE CONVENTIONAL DIFFERENTIAL as used in today's passenger cars and trucks offers definite limitations to their performance under the variety of driving conditions which may be encountered. As the performance characteristics of the passenger cars and trucks improved with the use of more and more powerful engines, owners became more dissatisfied with the lack of performance under adverse road conditions. The fact that the conventional differential has disadvantages is evidenced by the efforts that have been extended to overcome its limitations. Over 300 patents of devices to improve the conventional differential have been issued. A careful study of all types, including full-locking, bias or power dividing and over-running clutches established a number of requirements for a good locking differential:

1. It must maintain differential action.
2. It must prevent shock loads, and the transfer of full engine torque to any one axle shaft, which means that it should *not* be of the full-locking type.
3. It must provide sufficient traction torque to the non-spinning wheel at all times and under all operating conditions.
4. It must not interfere with steering.
5. It must be of long life and not subject to abnormal loads or wear.
6. It must continue to function efficiently regardless of wear.
7. It must be quiet in operation.
8. It must be of minimum cost, size and weight.
9. It must be a unit that could be used without major design changes in today's axles.

The Twin Traction differential fulfills all of these requirements and, in addition, possesses at least two more important features:

1. In the Twin Traction the torque capacity is increased over that of conventional differentials as the load is divided between the gear teeth and the clutches.
2. Action in the Twin Traction differential is the same for both drive and coast loads and forward and reverse driving.

Before analyzing the Studebaker-Packard Twin Traction differential, a brief discussion of the conventional differential may be in order. In this differential the amount of torque absorbed by the two wheels is equal under all conditions of driving. The reason for this is that a conventional differential is a gear set which permits the two wheels to rotate relative to each other while still transmitting torque to both wheels. The torque which is absorbed by one wheel plus the friction in the gear set between the two wheels is the only torque which can be transmitted to the other wheel. For example, with one wheel on a low friction surface, such as ice, and the other wheel on a high friction surface (dry concrete) the only torque that can be transmitted to the wheel on the high friction surface is the amount of torque absorbed by the spinning wheel plus the friction in the differential gear set.

Let us analyze the Twin Traction differential. The amount of power that can be transmitted to one wheel with a conventional differential is equal to that which is transmitted to the other wheel. However, by introducing friction in the differential, the amount of power that can be delivered to the other wheel can be increased. In the Studebaker-Packard Twin Traction differential we do exactly this by the introduction of clutches at each side gear. These clutches are the common flat disc type and resist rotation by the application of friction. They are designed so that they will slip and will not lock up. The application of load to these clutches is controlled by the reaction of the amount of torque applied to the differential. By having a means of introducing friction in the differential, suffi-

cient torque can be transmitted to the wheel having traction to move the vehicle. When the torque in the differential is decreased the friction in the clutch surfaces is also decreased and the Twin Traction then operates exactly the same as the conventional differential and the wheels are free to rotate relative to each other. (Figure 1.)

This Figure shows the Twin Traction differential as we are now using it. The torque is transmitted from the ring gear to the differential case to the cross pins and differential pinions to the side gears in the same manner as torque is applied in the conventional differential. The driving force moves the cross-pins "2" up the ramp of the cam surface "1," applying a load to the clutch rings "4," and restricts turning of the differential through the friction surfaces of the clutches at "5." This provides a torque ratio between the axle shafts which is based on the amount of friction in the differential and the amount of load that is being applied to the differential. When turning a corner this process is, in effect, partially reversed. The differential gears become a planetary gear set with the gear on the inside of the curve becoming a fixed gear of the planetary. The outer gear of the planetary over-runs as the outside wheel on the curve has a further distance to travel. With the outer gear over-running and the inner gear fixed, the pinion mates "3" are caused to rotate, but, inasmuch as they are restricted by the fixed gear they first must move the pinion mate shafts "2" back down the cam surface "1," relieving the thrust loads on the clutches "5." The engagement of the clutches on the Twin Traction unit provide many features that are not common in other types of locking differentials. On straight down-the-road driving, the clutches are engaged and thus prevent momentary spinning of the wheels when leaving the road or when encountering

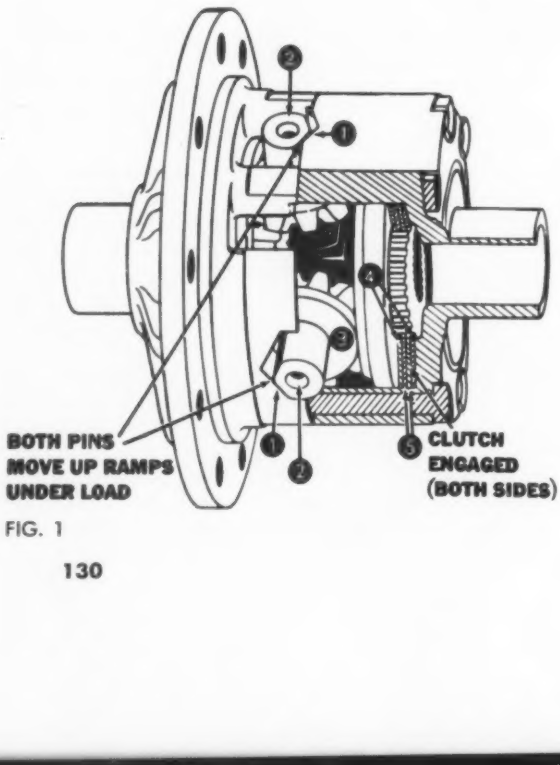


FIG. 1

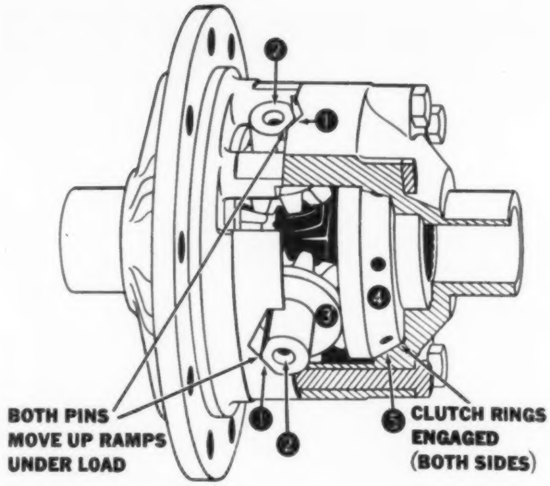


FIG. 2

poor traction. Field experience with the Twin Traction unit has indicated the shock loads imposed on the drive line and axles are less severe because wheel spinning is reduced to a minimum.

Types of Twin Traction Differentials we have used:

The basic design of the Twin Traction unit has not been changed since its adoption by Studebaker-Packard in 1956. Modifications to improve the performance have been made. The original design utilized a cone clutch to restrict rotation of the differential. (Figure 2.)

This unit was known as the 30-30 unit in that the cross-pin ramp angle and the friction ring cone angle were both 30 degrees. Although the performance of the unit was satisfactory, it did possess one inherent weakness, that of a slight chatter under a condition of a surge of torque with one wheel on a low-friction surface. (Figure 3.) The chatter was caused by a "stick-slip" action between the contacting friction sur-

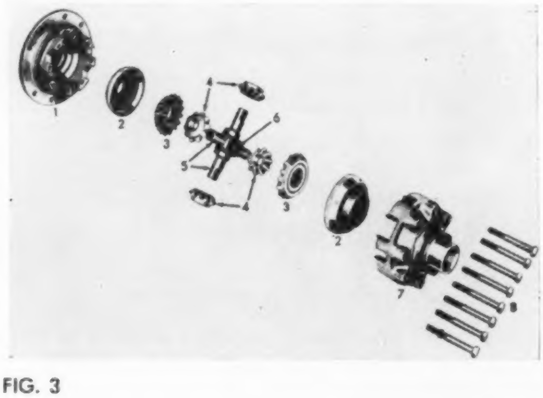


FIG. 3

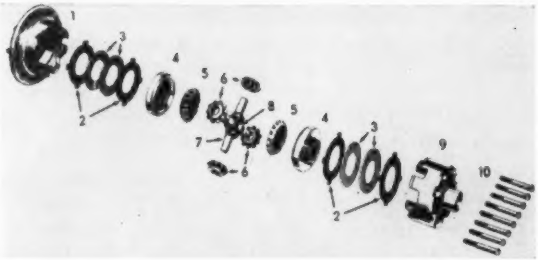


FIG. 4

faces of the cone clutch ring and the differential case.

In the second design (Figure 4) a multiple-disc clutch replaced the cone clutch. Four flat clutch plates, lubrized and cyanided, were used at either side of the differential. In each clutch pack, two of the plates were splined to the side gear ring and the remaining two plates rotated with the differential case through the use of drive lugs at the O.D. of the plate. Thus friction between the effective surfaces of the clutch plates produced a force restricting the relative movement between the differential pinion side gears and the differential case (Figure 5). The clutch plates in each pack were positioned so as to provide relative movement between three surfaces of the clutch discs. This unit was identified as the 30 degree ramp—3 friction surface disc clutch differential.

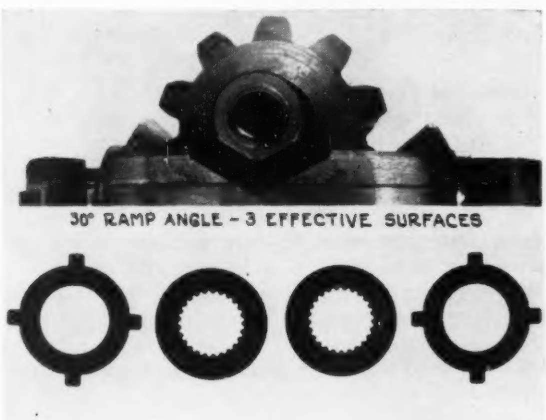


FIG. 5

The third and latest design included a change in the differential cross pin ramp angle and the number of effective clutch friction surfaces. The ramp angle was increased from 30 to 45 degrees to reduce the cross-pin travel required to engage the clutches. (Figure 6.) This resulted in a substantial decrease in drive line backlash which must be held to a minimum for smooth, quiet operation. It also followed that any increase in the cross-pin ramp angle decreased the clutch pack friction for any input load. In order to maintain the desired torque bias, it was necessary to increase the number of effective friction surfaces in the clutch packs. This was accomplished by repositioning the discs in the pack to provide five effective friction surfaces instead of the three effective surfaces as used with the 30 degree ramp.

The comparative torque multiplication factors of the three types of limited-slip differentials mentioned in the foregoing are as follows:

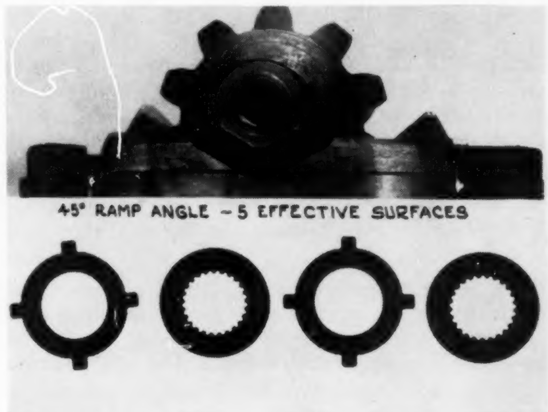


FIG. 6

The multiplication factor for the cone type with the 30 degree cone and ramp angles and the disc type with the 30 degree ramp angle and three effective clutch surfaces is approximately three to one. For the disc type with the 45 degree ramp angle and five effective clutch surfaces, the factor is approximately four to one. The torque multiplication factor is the constant by which the tractive torque of the "minimum" wheel is multiplied to determine the amount of tractive torque available at the "maximum" wheel or the wheel with the better traction. For example, the vehicle is equipped with a limited-slip differential having a multiplication factor of four to one. One driving wheel is on ice and has a tractive force of 50 pounds. The tractive force of the other wheel, which is on a surface having a higher coefficient of friction will be 50 pounds x 4 or 200 pounds. Thus, the vehicle will have a total tractive force of 250 pounds. Under identical conditions the vehicle with the conventional differential would have a total tractive force of only 100 pounds. Assuming a maximum coefficient of friction on concrete to be .7, with the three to one Twin Traction, you will note that full available driving force can be applied to the vehicle with one wheel on a surface having a coefficient of friction as low as .23. This range will cover approximately 80 per cent of all driving conditions. With the four to one Twin Traction the full available driving force can be applied to the vehicle with a co-

efficient of friction as low as .175. We have assumed that the coefficient of friction on concrete to be .7 and water on ice to be .1. These are the factors generally used by the tire manufacturers as being representative of actual field tests.

Problems Encountered with Limited-Slip Differentials

1. *Wheel Balancing*

The balancing of either rear tire and wheel assembly by a procedure which requires one of the rear wheels to be raised and spun is hazardous and is a practice which must be avoided in the interest of safety. Obviously, any abnormal friction in the spinning assembly, brake drag for example, would cause a torque transfer to the stationary wheel resulting in movement of the vehicle. Owner and service manuals warn of the dangers of this practice and all cars equipped with Twin Traction differentials carry an identification decal on the instrument panel.

2. *Limitations of the Limited-Slip Differential*

This differential, like many other new developments, is not a "cure-all" and it is entirely possible that a vehicle thus equipped may encounter abnormal road conditions wherein it will become stalled in spite of the best efforts of the skilled driver. The only assertion or claim made for this unit is that under actual driving conditions, the major driving force will be transmitted to the wheel having the better traction. It follows that in cases where the force resulting from the coefficient of friction between the driving wheels and road surface is less than the force required to move the vehicle, stalling will occur. However, this limitation has not proved to be a deterrent to the general acceptance of the Twin Traction differential. This is evidenced by the fact that more and more car manufacturers are offering the limited-slip differential as optional equipmment and also by the percentage increase in our own sales. In the 1957 models, 6.7 per cent of the Champion cars and 45 per cent of the Commander, President and Packard cars were factory equipped with the Twin Traction differential. Thus far, in the 1958 models, this percentage has increased to 12.8 per cent and 52 per cent respectively.

3. *The Problem of Lubrication*

The multiple-disc limited-slip differential unit possessed many advantages over the original cone type; however, it did present a new problem, that of chatter on sharp turns under drive load conditions. Due to the low noise level of the chatter it was believed that it would not be a source of owner complaints or concern. It was also determined that the "stick-slip" action between the plates, the source of the chatter noise, caused no material damage to the plate surfaces. Subsequently it was released for production in January of 1957. The sulphur-chlorine-lead-base oil, identified as lubricant "A," which has been used by us for several years with excellent results, was specified for use with this unit.

Test work directed toward the elimination of the chatter noise was continued. In the main, these tests consisted of a comparative evaluation by road tests of lubricant "A" versus other available gear lubricants. A summary of the results clearly revealed these two important findings:

1. Approximately 85 per cent of the axles lubricated with lubricant "A" and observed on the road tests were classed as passable. The remaining 15 per cent were classed as being borderline cases or barely passable. This data was obtained by the Dana corporation from tests conducted on several different makes of vehicles. Our own experience in the field did not concur with these findings. Approximately 50 per cent had chatter considered highly objectionable by the owners.
2. No objectionable noise was observed in any of the axles lubricated with lubricant "B."

As a result of these tests, the immediate program was focused on obtaining additional road test data on lubricant "B." Samples of this lubricant were forwarded to some of the "hot" spots in the field and in addition the axles of several engineering employees' cars were serviced with lubricant "B."

The results were very gratifying and in no case did this lubricant fail to eliminate all objectionable chatter noises. With this background of test work and also with approval of The Dana corporation, lubricant "B" was immediately released for factory filling and service in all vehicles equipped with Twin Traction.

The next phase in resolving the problem of lubrication was to determine whether or not lubricant "B" would serve as a break-in lubricant to be successfully replaced after an "X" number of miles by lubricant "A" or other approved multi-purpose S.A.E. 90 gear oils. I am sure that it is obvious that this exploration was done in an attempt to eliminate the need for the recommendation of one specific lubricant for servicing in the field. In this connection, extensive tests were run at our proving ground with cars equipped with the disc type differential and lubricated with lubricant "B." At each 1000-mile interval, lubricant "B" was drained and replaced with lubricant "A."

The car was then ridden for the chatter noise check and then continued on test after refilling the housing with lubricant "B." The test was concluded after 15,000 miles. In each instance, after refilling with lubricant "A," the chatter noise returned within a period of 25 miles of driving.

Summing up the data obtained on our road tests, which included the testing of nine sample lubricants submitted, the following results were evident:

1. Only one lubricant, namely Lubricant "B," of the nine sample lubricants tested, successfully

Continued on page 134

STUDEBAKER ENGINEERING STANDARDS

S.A.E. 90 Hypoid Gear Lubricant Specification

(1) This specification covers an extreme pressure lubricant for use in Hypoid Rear Axles when and as designated on the Lubrication Chart for each model car.

(2) It shall be a well refined mineral oil properly compounded with Sulphur-Chlorine-Lead type extreme pressure additives.

(3) It shall be free of fillers and abrasives such as fullers' earth, talc, graphite, cork, etc. It shall be stable, non-abrasive and non-corrosive to the materials used in rear axle construction whether or not in the presence of small percentages of water.

(4) Physical & Chemical Properties

Viscosity at 100 deg. Fahr.	1400 Secs. Max. (S.U.V.)
Viscosity at 210 deg. Fahr.	90 to 100 Secs. (S.U.V.)
Viscosity Index	85 Min.
Flash Point	350 deg. Fahr. Min. (Cleveland Open Cup)
Pour Point	-10 deg. Fahr. Max (A.S.T.M. D97-39)
Lever Load, Timken Test	68 lbs. Min.
Active Sulphur	1.00% Min.
Chlorine	1.00% Min.
Lead (As Lead Oxide)	1.50% Min.
Moisture	.20% Min.

(5) *Heat Test*: 200 Grams of the lubricant placed in a 400 c.c. beaker, 3 inches in diameter, and heated for a total of 125 hours at 185 to 200 deg. Fahr. in an electric oven without circulating fan shall not show a change in the viscosity at 210 deg. Fahr. of over 10% nor an evaporation loss of over 4%.

(6) Before the product of a supplier is approved service tests must be made in test cars, and satisfactory performance must be obtained from the lubricant.

(7) A portion of this test lot of lubricant will be retained by the Laboratory Division as a standard type sample to which subsequent shipments must conform.

(8) All containers shall be stencilled "M.S. 914" by the vendor, the figures being not less than 2 inches high.

(9) Shipments which do not meet the above specifications are subject to rejection.

FIG. 8

STUDEBAKER ENGINEERING STANDARDS

Twin Traction Differential Lubricant

(1) This specification covers an extreme pressure lubricant for use in Hypoid "Twin Traction" Differentials.

(2) It shall be a well refined mineral oil properly compounded with fatty oils and sulfur and phosphorus extreme pressure additives.

(3) It shall be free of fillers or abrasives such as fullers' earth, talc, graphite, cork, etc. It shall be stable, non-abrasive and non-corrosive to the materials used in rear axle construction whether or not in the presence of small amounts of water.

(4) Physcial & Chemical Properties

		ASTM Test
Viscosity, S.U.S. at 100°F.	1400 max.	D-439
Viscosity, S.U.S. at 210°F.	85 Min	D-439
Viscosity Index	90 Min.	D-567
Flash Point, °F.	350 Min.	9-92
Pour Point, °F.	410 Max.	D-97
Timken Test, lbs. lever load	50 Min	———
Fats, %	15-18	———
Sulfur, % by weight	2.50 Min.	D-129
Phosphorus, % by weight	.03-.045	D-1091
Moisture, %	0.20 Max.	D-95

(5) *Heat Test*: 200 Grams of the lubricant placed in a 400 c.c. beaker, 3 inches in diameter, and heated for a total of 125 hours at 185 to 200 deg. Fahr. in an electric oven without circulating fan shall not show a change in the viscosity at 210 deg. Fahr. of over 10% nor an evaporation loss of over 4%.

(6) Before the product of a supplier is approved service tests must be made in test cars, and satisfactory performance must be obtained from the lubricant.

(7) A portion of this test lot of lubricant will be retained by the Laboratory Division as a standard type sample to which subsequent shipments must conform.

(8) All containers shall be stencilled "M.S. 907" by the vendor, the figures being not less than 2 inches high.

(9) Shipments which do not meet the above specifications are subject to rejection.

FIG. 9

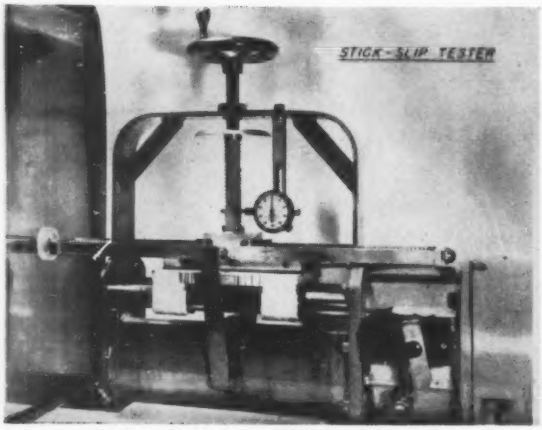


FIG. 10

eliminated all objectionable chatter noise.

2. Lubricant "B" does not serve as a "break-in" lubricant to be replaced at a later date with an approved Multi-purpose gear lubricant.

In concluding this portion of the paper we wish to have it understood that all of the data and material presented in the foregoing was based upon our experience with the limited-slip differential as used and as tested in Studebaker-Packard vehicles.

The problem of selecting the proper lubricant for the Twin Traction differential is complicated by the presence, in one housing, of two different mechanisms. The gearing demands an extreme-pressure lubricant, while the clutch plates, which provide limiting differential action, seem to be satisfied only when fed lubricity agents whose polar attraction makes the plate surfaces slip smoothly against each other.

Figure 8 depicts a typical specification for a hypoid lubricant, the aim of which is to prevent scoring of gears under combinations of high and low speed and high and low torque—especially during wear-in. We originally used this type of lubricant for initial fill on the Twin Traction differential because all our experience told us that it would perform satisfactorily. The clutch plates, however, were more sensitive than expected, so we eventually changed over to the lubricant described in Figure 9. Here a compromise was reached on extreme pressure value, as measured on the Timken machine, being dropped from 68 to 50 pounds lever load minimum. Note, too, that this specification requires that the lubricant offered must pass performance tests in cars as well as meet chemical and physical properties.

The special care to specify a lubricity additive stemmed from the experience of the Packard division who were first to make available a production limited-slip differential, plus experience in our South Bend test cars. The sound waves sent out by clutch plates protesting improper lubrication result from a phenomena known as "stick-slip." This phenomena can be minimized with lubricant additives which act by producing a film of low shear strength on the friction surfaces.

A paper given by Dr. Eugene Merchant of Cincinnati Milling at an A.S.L.E. meeting in 1946 shows that the polar type additive, characterized by an asymetrical organic molecule having a large electric moment, was best suited in providing "oiliness" when used in a lubricant in small percentages. It is, of course, necessary to know that the polar compound used does indeed produce a polar film, for such is not always the case. Work on this thesis was done on a "Stick-Slip" Test Machine, views of which are shown here. (Figure 10.)

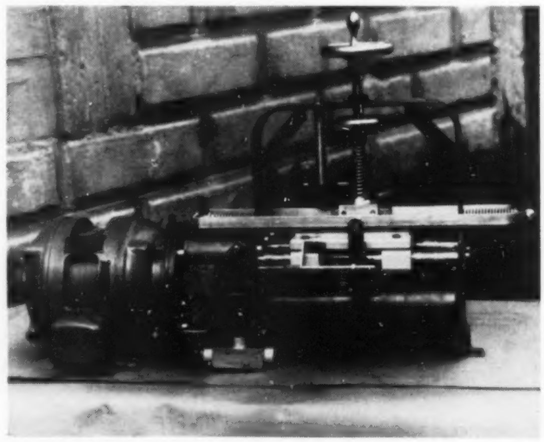


FIG. 11

In this machine a cast iron block coupled to an actuating screw, rubs against another cast iron block which is pressed down on the moving block by a spring and screw arrangement so that various pre-selected loads may be applied. The amount of horizontal displacement of the upper block from its neutral position under the action of the frictional force exerted on it by the lower block, is read by means of a dial indicator. Readings are taken when the lower block is moving to the right and when it is moving to the left. Total displacement, then, is the sum of the displacement in both directions. For "smooth sliding" the slip is the distance traversed going to rest when the machine is stopped. "Stick-slip" on the contrary, is the displacement due to the oscillating motion transmitted to the gage (Figure 11). Using mineral oil as the lubricant, it was found that carbon tetrachloride, an extreme pressure additive, would prevent stick-slip only when present in high percentages; whereas oleic acid, a polar compound, prevents stick-slip at molar percentages as low as 0.2. We have proved many times that a moderate amount of polar additive is necessary to prevent noise

Conversion Values for the Stick-Slip Machine Displacement vs. Coefficient of Friction

	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
8	.0708	.0717	.0726	.0735	.0743	.0752	.0761	.0770	.0779	.0788
9	.0797	.0805	.0814	.0823	.0832	.0841	.0850	.0859	.0867	.0876
10	.0885	.0894	.0903	.0912	.0920	.0929	.0938	.0947	.0956	.0965
11	.0974	.0982	.0991	.1000	.1009	.1018	.1027	.1036	.1044	.1053
12	.1062	.1071	.1080	.1089	.1097	.1106	.1115	.1124	.1133	.1142
13	.1151	.1159	.1168	.1177	.1186	.1195	.1204	.1213	.1221	.1230
14	.1239	.1248	.1257	.1266	.1274	.1283	.1292	.1301	.1310	.1319
15	.1328	.1336	.1345	.1354	.1363	.1372	.1381	.1390	.1398	.1407
16	.1416	.1425	.1434	.1443	.1451	.1460	.1469	.1478	.1487	.1496
17	.1505	.1513	.1522	.1531	.1540	.1549	.1558	.1567	.1575	.1584
18	.1593	.1602	.1611	.1620	.1628	.1637	.1646	.1655	.1664	.1673
19	.1682	.1690	.1699	.1708	.1717	.1726	.1735	.1744	.1752	.1761
20	.1770	.1779	.1788	.1797	.1805	.1814	.1823	.1832	.1841	.1850
21	.1859	.1867	.1876	.1885	.1894	.1903	.1912	.1921	.1929	.1938
22	.1947	.1956	.1965	.1974	.1982	.1991	.2000	.2009	.2018	.2027
23	.2036	.2044	.2053	.2062	.2071	.2080	.2089	.2098	.2106	.2115
24	.2124	.2133	.2142	.2151	.2159	.2168	.2177	.2186	.2195	.2204
25	.2213	.2221	.2230	.2239	.2248	.2257	.2266	.2275	.2283	.2292
26	.2301	.2310	.2319	.2328	.2336	.2345	.2354	.2363	.2372	.2381
27	.2390	.2398	.2407	.2416	.2425	.2434	.2443	.2452	.2460	.2469
28	.2478	.2487	.2496	.2505	.2513	.2522	.2531	.2540	.2549	.2558
29	.2567	.2575	.2584	.2593	.2602	.2611	.2620	.2629	.2637	.2646
30	.2655	.2664	.2673	.2682	.2690	.2699	.2708	.2717	.2726	.2735
31	.2744	.2752	.2761	.2770	.2779	.2788	.2797	.2806	.2814	.2823
32	.2832	.2841	.2850	.2859	.2867	.2876	.2885	.2894	.2903	.2912
33	.2921	.2929	.2938	.2947	.2956	.2965	.2974	.2983	.2991	.3000
34	.3009	.3018	.3027	.3036	.3044	.3053	.3062	.3071	.3080	.3089
35	.3098	.3106	.3115	.3124	.3133	.3142	.3151	.3160	.3168	.3177
36	.3186	.3195	.3204	.3213	.3221	.3230	.3239	.3248	.3257	.3266
37	.3275	.3283	.3292	.3301	.3310	.3319	.3328	.3337	.3345	.3354
38	.3363	.3372	.3381	.3390	.3398	.3407	.3416	.3425	.3434	.3443
39	.3452	.3460	.3469	.3478	.3487	.3496	.3505	.3514	.3522	.3531
40	.3540	.3549	.3558	.3567	.3575	.3584	.3593	.3602	.3611	.3620
41	.3629	.3637	.3646	.3655	.3664	.3673	.3682	.3691	.3699	.3708
42	.3717	.3726	.3735	.3744	.3752	.3761	.3770	.3779	.3788	.3797
43	.3806	.3814	.3823	.3832	.3841	.3850	.3859	.3868	.3876	.3885
44	.3894	.3903	.3912	.3921	.3929	.3938	.3947	.3956	.3965	.3974
45	.3983	.3991	.4000	.4009	.4018	.4027	.4036	.4045	.4053	.4062
46	.4071	.4080	.4089	.4098	.4106	.4115	.4124	.4133	.4142	.4151
47	.4160	.4168	.4177	.4186	.4195	.4204	.4213	.4222	.4230	.4239
48	.4248	.4257	.4266	.4275	.4283	.4292	.4301	.4311	.4319	.4328
49	.4337	.4345	.4354	.4363	.4372	.4381	.4390	.4399	.4407	.4416
50	.4425	.4434	.4443	.4452	.4460	.4469	.4478	.4487	.4496	.4505

FIG. 13

from stick-slip in the Twin Traction unit, but our efforts to arrive at a test to screen lubricants for this property have been somewhat less than satisfactory.

We ran tests on a stick-slip machine between Product A and Product B, finding that Product B (containing fats) was indeed slightly better than Product A from the standpoint of a lower coefficient of sliding friction, on the order of 0.15 against 0.20. We can only surmise that this difference, as small as it is, means the difference between noise or no noise in the Twin Traction differential.

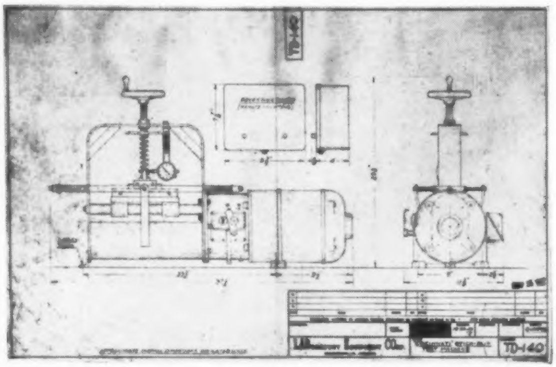


FIG. 12

This, then, is one challenge: Find some quick, easy, and inexpensive method of evaluating the stick-slip properties of a formulated lubricant. Determination of fat content is very difficult in the presence of active sulfur, and even should the amount of such a polar compound be determined, possible nullifying effect of other additives complicates the picture. (Figure 12.)

Coefficient of friction figures by the Shell 4-Ball wear tester are much lower than figures obtained with the slip-stick machine, probably due to steel used and point contact used instead of large surface contact. Another possibility is the Bowden machine which measures coefficient of sliding friction by moving a loaded hard steel ball over a highly polished low-carbon steel plate. This equipment was used by the Naval Research laboratory for data given in N.R.L. Report No. 3680 on "Surface Chemical Phenomena in Lubrication," in which they deal with:

1. Physical adsorption,
2. Chemical reactions at solid-liquid interface,
3. Colloidal behavior of polar molecules in non-aqueous liquids, and
4. Activity of liquid lubricant phase as a source of or sink for surface-active materials.

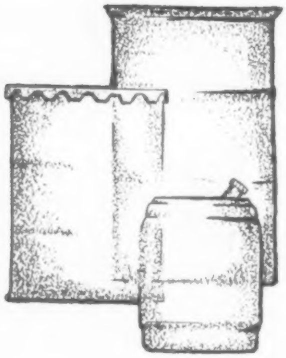
Since the Twin Traction differential results in customer satisfaction, it is here to stay; hence, answers to lubrication problems must be found. At a National Petroleum association meeting in Atlantic City last Fall, a "Symposium on Gear Oil Developments" took definite recognition of the part that limited-slip differential lubrication demands would play in formulating, for instance, a reference gear oil for GL-4. Certainly the primary anti-score emphasis will have to be de-emphasized in favor of a compromise lubricant suited to the appetite of this rapidly growing infant, the Twin Traction differential.

We are concerned about the fact that only *one* lubricant is currently available which totally prevents the chattering of plates, and even that one is available only as initial fill and through our dealer organization. It is not available at filling station level. Further, not even one satisfactory product is available in foreign lands—a fact which assumes tremendous importance in view of the restrictions against importing set up by Mexico, for example. ■

About the Authors

ORVILLE K. BUTZBACH *graduated from the University of Michigan in 1926 with a BS in electrical engineering. He joined the Studebaker corporation in September of the same year as test observer at the proving ground. In 1929 he was transferred to the engineering research department working on the development of transmissions, rear axles, steering gears, propeller shafts and frames. From 1941 to 1943 he worked on the development of many military vehicles including the Weasel, flotation of the light tank and tank trainer units. He served as proving ground test engineer from 1943 through 1955. Mr. Butzbach became chassis development engineer in 1956.*

PAUL IZDEPSKI *graduated from Ripon college in 1939 with a BS in physics and chemistry, and was employed as a production worker by Studebaker corporation in 1940. He was moved to the chemistry laboratory in 1942 in conjunction with the Wright cyclone engine program and was inducted into the Corps. of Engineers in 1945. He was assigned, during World War II to the atom bomb project at Oak Ridge, Tenn. Mr. Izdepski rejoined Studebaker following World War II as a lubrication engineer and was promoted in 1957 to supervisor of chemistry in the manufacturing research dept.*



Packaging— An Essential Service

By A. D. Murphy
Standard Oil (New Jersey)

Presented at the NLGI 25th annual meeting in Chicago, October, 1957

FOR A PERIOD OF over thirty-five years the subject of grease packages lay dormant; people and companies were apparently satisfied with a wide variety of sizes and shapes which the suppliers were furnishing. Metal packages varied not only between manufacturers, but between plants of the same companies. Four different dimensions and shapes were prevalent from the west coast to the east coast on the old 100 pound capacity grease keg. Both the filling plants and the customers had handling difficulties, and the poor service station and industrial users were greatly confused.

This condition existed until the late 1940's, when a representative of a dispensing equipment manufacturer appealed to the National Lubricating Grease Institute for standardization of the 100 pound keg throughout the industry, pointing out the many advantages of uniformity. The NLGI thought the suggestion had merit.

Since the Joint Container Committee NLGI-API had no working subcommittee, the problem was given the subcommittee on metal drums and pails of the newly formed Petroleum packaging committee of Packaging Institute, Inc. with the understanding that all recommendations would be submitted to the NLGI-API Container Committee for approval and member company reaction. This policy has been carried out on all recommended standards.

The approach on the 100 pound keg problem was to get together with the various interested parties to establish a program. The committee met with representatives of the steel container manufacturers, the dispensing equipment producers, and the east-west users. There is an old adage which seems appropriate at this time "there is nothing resisted so much as change" and we ran into resistance, but the committee did a good sales job on the resistors. They considered all of the drum diameters and settled on one which would cause the least die expense to the manufacturers. At this point, it should be noted that all of our work was done toward the end that no one would be burdened with excessive expense. It was understood from the inception of the program that there would be an "interim period" before all suppliers would be equipped.

In surveying the heights of kegs produced, the committee was guided by the amount of steel which would give a minimum cost with a maximum capacity. After many meetings with all interested parties, they decided upon the size and shape with which most of you are familiar, namely 13-15/16 inches I. D. x 25-⅞ inches I. H., nominal net contents of product 120 pounds.

At the same time, the committee thought that a full removable head was superior to the old nine inch lug covered opening in the head, and they therefore studied a new contour for the head and increased the number of lugs from sixteen to 20 in order to insure a tighter closure.

The recommended standard gave 20 per cent greater capacity at an increase in cost of approximately 8 per cent. This added to the factors of standard pattern for palletization, plus the uniform dispensing units created an acceptance by a large segment of the grease manufacturers and users. At last review about 80-85 per cent of the industry had adopted the 120 pound capacity universal standard grease keg. Anything that this group can do to encourage the others to accept the new package would be appreciated.

While one committee was working on the 120 pound keg, another was working on the standardization of cans. As you all know, your group approved the dropping of the 10 pound size in favor of the 5 pound. This left the 1 pound and 5 pound cans and 35 pound lug covered pail as recommended standards

for the small sizes. The key-opening type 1 pound can has been adopted by several companies, and it is my understanding that it is now acceptable to the Armed Forces.

With problem of the universal 120 pound grease keg solved, the group went to work on the 400 pound capacity full removable head grease drum and the tight head so-called 55 gallon oil drum. The joker in the latter case was that it could not be filled to 55 gallons and allow for the regulation outage. The investigation also disclosed that the oil industry had been paying an extra for the convex head construction, when such was required. The committee found both types varied in dimensions as much as 2 inches in height and 1 inch in diameter, not only between manufacturing companies, but between plants of the same manufacturer. Here again it was realized that the minimum hardship should be placed on the drum companies. After receiving data on sizes of drums, plant by plant, a composite was set up and by slightly increasing certain dimensional areas, plus the convex heads a total capacity of 57.75 U. S. gallons at 60°F. was arrived at. They also found that in the manufacturing of the convex heads no extra charge was justified, and therefore, a saving resulted. Now it is possible to fill to 55 gallons—an added one or two gallons depending on past company filling practices.

The 400 pound full removable head drum shell followed the dimensional changes of the tight head package. Work is now being conducted to try to further improve other features of this drum.

A very comprehensive program under the co-sponsorship of the Steel shipping container institute, the Chemical packages committee of the Manufacturing chemists association, and your working committee, namely the Petroleum packaging committee has been set up. For the first time the closing ring contour, length and closing mechanism are to be studied. Gasket material, sizes and shapes will be reviewed as well as a protective rolling hoop positioned to protect the closing ring from shock or other deforming factors. In addition work will be done on improving the contour of the full removable head, so that drop test on regulatory products will not greatly distort the head causing leakage at the locking ring.

The "so-called "lubester", which had a capacity of fourteen gallons, was changed to conform to the dimensions of the 120 pound keg, thereby increasing capacity two gallons to a total of sixteen.

A study is now underway to review new and better features of the 35 pound and five gallon lug covered pail.

Let us now explore the thinking we should be doing for the grease containers of the future. Some radical changes may be forced upon us, particularly as the price of steel containers has risen well over 100 per cent and will continue to rise as the cost of steel goes up. What can we do about it?

Here are some of the possibilities—Tests are being conducted by certain member companies of the NLGI on 120 pound kegs having fibre bodies and metal tops—with metal flange at bottom to hold the fibre bottom in place. Certain advances in construction have been made and plastic film laminates look promising. Another experiment being considered would require a change in customer thinking, but considerable saving package-wise could accrue—the use of a resin film bag filled with grease (say 50 pounds, shipped in a corrugated carton. This might require the user to transfer the grease to dispensing equipment for use. The 35 pound pail now used could be constructed with a fibre body, similar to the 120 pound size. However, the saving on the smaller unit is not as great.

Paper laminates should be considered on the one and five pound units, something along the line of the Tetra-pak now used for milk and orange juice.

These are changing times and the accepted practices of yesteryear are gone today as will those of today be gone tomorrow. Changes in packaging, distribution and marketing are undergoing change and will continue to. Things that were scoffed at as possibilities today will become the realities of the future. So when someone suggests an idea in packaging of your products don't be too quick to reject it. If we are to survive economic pressures we must think broadly and daringly of the grease packages of tomorrow. ■

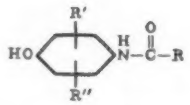
About the Author

A. D. Murphy, *package coordinator and chairman of the Package advisory committee of Standard Oil company (New Jersey) has been with the company for 40 years—28 years in the packaging activity. Murphy was the first oil man to be elected to the presidency of the Packaging Institute, Inc., a technical group dedicated to all phases of packaging. Past chairman of the Petroleum packaging committee and one of its founders, Murphy has been one of the leaders in establishing universal packing standards.*

Patents and Developments

Soap-Salt Complex Grease Containing N-Acyl-p-Aminophenol

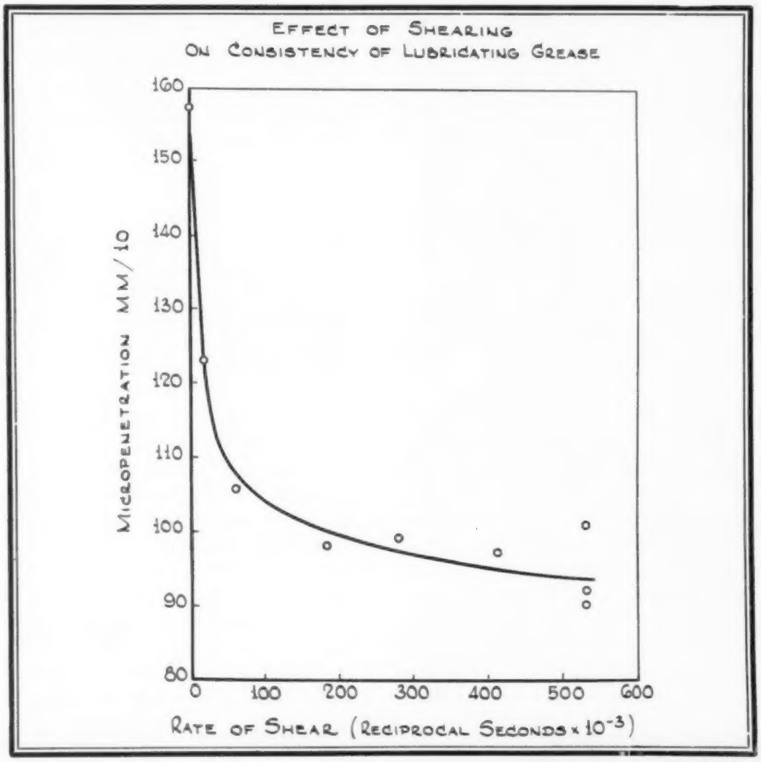
Patent No. 2,824,837 issued to A. J. Morway, assigned to Esso Research and Engineering company. Outstanding high temperature grease compositions are claimed to be produced containing complex alkaline (preferably calcium) soap wherein the soap system consists of a combination of the soap of high and low molecular weight fatty acids, the low molecular weight acid predominating, which contains combined therein a minor but stabilizing proportion of an n-acyl-p-aminophenol having the following general formula:



wherein R is an alkyl group containing 10-22 carbon atoms, and R' and R" are hydrogen atoms or alkyl groups containing 1-20 carbon atoms. Examples of such N-acyl aminophenols include N, n-valeryl-4-amino-3-pentadecyl phenol, N-lauroyl p-aminophenol, etc. The low molecular weight monocarboxylic acid of the complex contains 2-6 carbon atoms and the molar ratio of its salt to the high molecular weight acid soap (e.g. calcium soap of hydrogenated fish acids) in the complex is about 7.5:1 to 20:1, the complex being used in an amount of 8-20 weight percent. The N-acyl-p-aminophenol is employed in amounts of 1-6 per cent.

High Temperature Lubricating Grease

Patent No. 2,825,694 issued to A. J. Morway and assigned to Esso Research and Engineering company. A novel process for preparing greases having ASTM penetration values of 200-350 mm./10 which uses a technique involving the application of shearing forces without concurrent mixing to obtain maximum soap dispersion and involves preparation of the mixture of complex soap (20-50 per cent soap) and a mineral oil, adding



additional oil to reduce the overall soap content to 6-18 per cent soap, and hardening it to the desired consistency by application of shearing forces within the range of 100,000-500,000 reciprocal seconds under stream-lined conditions. An example describes saponifying rapeseed oil with caustic soda in presence of a hydrocarbon by heating in the presence of free alkali to dehydrate the material. Then, additional mineral oil is added while stirring, and the mixture is heated to 480°-520°F., cooled to a temperature below the transition temperature of the soap, and additional mineral oil is added to reduce the soap content, and the mixture is subjected to shearing action under streamlined conditions. The complex soap preferably is prepared by subjecting furfural to the Canizzaro reaction, and the shearing action is achieved with a unit such as the Gaulin homogenizer. The accompanying figure illustrates the effect of shearing on the consistency of the grease. The hardening effect is most pronounced at shear rates up to 100,000 reciprocal seconds. Although application of rates of shear up to 500,000 reciprocal seconds is also effective, the differential is less than at the lower rates.

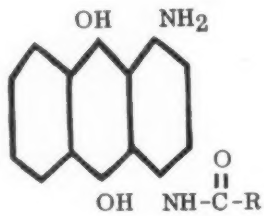
Lithium Greases Containing Naphthenyl Diesters

Patent No. 2,824,065 issued to S. E. Jolly, and assigned to Sun Oil company. Synthetic lithium greases possessing superior lubricating properties, having a clear and buttery appearance and improved penetration characteristics are produced by replacing a part of the aliphatic ester lubricant with a naphthenyl ester of a dibasic acid, i.e., in an amount of at least 10 per cent. If more than about 50 per cent of the aliphatic ester is replaced by the naphthenyl ester, the lubricant base may have a viscosity higher than desirable for most applications, although it

could be useful in special applications. A suitable grease with lithium hydroxystearate was made by using 70 per cent "Plexol 20" (dioctyl sebacate) and 30 per cent dinaphthenyl sebacate. It is believed that the naphthenyl ester may act as a mutual solvent for the soap and the aliphatic ester and also may act as a crystallization inhibitor during the cooling of the grease to prevent formation of grainy soap fibers.

Grease Containing Acyl Derivatives of Dihydroxy Diamino Anthracene

U. S. Patent 2,816,074 issued to D. L. Cottle, D. W. Young and A. J. Morway, assigned to Esso Research and Engineering company. Structurally stable lubricating greases containing a minimum of ash-forming soaps are prepared by incorporating 1.5-5 weight per cent of acyl derivatives of 9,10-dihydroxy-1,4-diamino anthracene having the generic formula as follows:



wherein R is an alkyl group containing 3-24 carbon atoms. The compound can serve a dual purpose of oxidation inhibitor and thickening agent. Suitable compounds include N-stearoyl diamino dihydroxy anthracene and similar materials. They are advantageously used in conjunction with calcium acetate and the calcium soap of hydrogenated fish oil acids.

Sodium Soap Thickened Extracted High Viscosity Index Oil

Patent No. 2,824,066 issued to J. M. Musselman and C. P. Nunley, assigned to The Standard Oil company (Ohio). A sodium soap grease which has excellent water and oxygen resistance and which can be classed as a true multi-purpose grease is produced by employing a fatty acid having an iodine value of preferably less than three, and composed preferably of at least 85 per cent by weight of C_{18} or higher acids, containing preferably less than 15 per cent of C_{16} acids, and preferably less than 1 per cent of C_{14} and lower acids. There is no critical limit on the maximum chain length of the fatty acid. There is no naturally occurring oil or fat whose fatty acid content meets these specifications, and it is necessary to subject them to processing to obtain the desired acid. For example, one meeting the

specifications can be prepared by hydrogenating fish oil to reduce the iodine value and then fractionating out the lower acids. The solvent extracted oil which is combined with the sodium soap of the aforesaid fatty acids need not be selected so carefully. However, it must have a viscosity index preferably of at least 115°C., a viscosity within the range of 100-2000 SSU at 100°F., and a pour point of 10°F. or below. Pour depressants may be used, and although V.I. improvers may be permissible, they are generally not practicable. Preparation of the grease preferably involves the in situ formation of the fatty acid soap in the oil. Other ingredients which may be added are antioxidants such as "Calco MB" (tetramethyl diamino diphenyl methane), etc.

News Items

Radiation damage in lubricating greases: When exposed to radiation, greases usually soften and then harden. This can be reduced by using synthetic aromatics such as sodium N-octadecylterephthalamate instead of conventional gelling agents and oils. (Hotten, Ind. & Engrg. Chem., 2/5/58 p. 217).

Contact of metallic bodies: Effect of tangential force—British tests showed that a lubricant does not affect deformation process for tangential forces less than those needed to cause slip; It acts by weakening the surface interaction, and slip occurs for a smaller tangential force. (Courtney-Pratt, Engineering, 2/7/58, p. 182.)

The new ETR greases for high temperature-high speed lubrication in missiles and supersonic aircraft can withstand up to 600°F and protect metal parts at 30,000 rpm according to Shell Oil. An "organic vat dye" acts as a thickener to improve heat stability and gelling efficiency (Oil, Paint & Drug Rep. 12/23/57, p. 5, N. Y. *Times* 1/11/58, p. 29).

People in the Industry

Howard P. Ferguson Appointed Manager by Standard Oil Co.

NLGI Board member Howard P. Ferguson has been appointed manager of the wholesale and subsidiary sales in the home office of The Standard Oil company (Ohio) in Cleveland, Ohio effective on the retirement of veteran John J. Adams, according to an announcement by Samuel H. Elliott, vice-president in charge of marketing.

Mr. Ferguson was born in Paterson, N. J. and is a chemical engineering graduate of Massachusetts Institute of Technology. Since 1954 he has been and will continue to be manager of lubricating oils sales in marketing's general office sales section, after having served since 1932 in various posts in the company's manufacturing department, such as manager of Sohio's refinery control division and later manager of the Sohio No. 2 refinery in Cleveland.

In 1950 Mr. Ferguson received an award of merit from the American Society for Testing Materials for his work in developing standards and tests for petroleum products. In 1944 he shared in recognition given the coordinating Research Council by the Army's Ordnance department for work its membership had done on war research problems. He has been a member of the NLGI Board of Directors since 1955.

Mr. Ferguson has served on the Institute's awards, NLGI SPOKESMAN, program and membership committees, in addition to being NLGI's liaison representative on the API-NLGI joint container committee and liaison with SAE.

Du Pont Promotes Carpenter

W. Samuel Carpenter, 3rd director of sales of Du Pont's petroleum

chemicals division, became assistant general manager of the company's electrochemicals department May 1.

He succeeds Charles B. McCoy who has been named general manager of the elastomer chemicals department.

Mr. Carpenter, a son of Walter S. Carpenter, Jr., chairman of the board of directors of Du Pont, has been with the company for more than twenty years, starting as an industrial engineer at the Chambers works, Deepwater Point, N. J.

Two years later he was transferred to Wilmington, joining the planning section of the nylon division. He returned to the Chambers works in 1942 and in 1944 was assigned to the construction division of the engineering department at the Hanford, Washington, Engineer works, the government's atomic energy project designed and operated by Du Pont during the war.

Mr. Carpenter returned to Wilmington in 1945 and the next year he became manager of the planning division of the engineering department and later manager of the industrial engineering division.

In 1947 he became assistant to the director of production of the rayon division of the rayon department and in 1949 became assistant manager of "Cordura" yarn sales. He was appointed manager of the rayon division's planning section in January, 1950, and in August was made assistant manager of the rayon department's planning division. Subsequently he was assistant director of rayon production.

With the reorganization of the rayon department as the textile fibers department, he was made director of manufacturing for acetate on December 1, 1951. He was appointed director of manufacturing for rayon on May 1, 1952, and became director of manufacturing for the cellulosics division on December 9, 1954.

Becomes Director of Sales

Mr. Carpenter was transferred to the organic chemicals department as assistant director of sales of the petroluem chemicals division on July 18, 1955, and in March, 1957, advanced to director of sales of that division.

Born November 1, 1915, in Wilmington, he attended Tower Hill and Taft schools, and in 1938 was graduated from Princeton University, receiving the degree of bachelor of science in chemical engineering.

John F. Trevenen Succeeds J. J. Walsh As Manager

Penola Oil company, a marketing affiliate of Esso Standard Oil company, has announced the appointment of John F. Trevenen as manager of its wholesale lubricating oils department. He succeeds John J. Walsh, who recently was elected vice president.

Mr. Trevenen comes to Penola from the United States Refining company, of Warren, Pa., where he was general sales manager. He had been a marketing official of the Warren firm since 1939.

Began as Office Boy

He began his career in the oil business as an 18-year-old office boy for Standard Oil company (N. J.), parent company of Esso Standard and Penola. His first job was in the office of the late F. H. Bedford, Sr., then vice president in charge of foreign and domestic lube-sales.

Later he was in charge of shipping of lubricating oils for the Esso Export corporation, and served in the wholesale lube department of Esso Standard.

Penola markets lubricating oils, waxes, greases and other petroleum specialty products, both in this country and overseas.

Dr. Ira Kukin Made Research Director by L. Sonneborn Sons, Inc.

The appointment of Dr. Ira Kukin as research director at the Bellville, N. J., plant of L. Sonneborn Sons, Inc., was announced by Rudolf G. Sonneborn, president. In this capacity he will be in charge of research and development on petroleum and textile products for the company—well known petroleum refiners and manufacturing chemists.

Dr. Kukin joined L. Sonneborn Sons, Inc., in 1957 as liaison chemist in the department of industrial research. He came to Sonneborn following six years with the Gulf Oil company where he was a group leader in charge of fundamental research. Prior to joining Gulf, he served as an instructor in chemistry at Sampson college at Lake Geneva, New York.

He has published extensively in the field of colloid chemistry and spectrophotometric analysis, and has several patents on chemical engineering processes and fuel oil additives.

Dr. Kukin received his A.MA. in chemistry in 1949, and his Ph.D. in 1951—both from Harvard university. He was graduated with a B.S. degree in 1945 from the college of the City of New York.

Dr. Kukin is a member of the American Chemical society, Sigma Xi, New York Academy of Sciences, and the American Association for the Advancement of Science. He is also active in the American Technion society and formerly served as a secretary of the Pittsburgh chapter of that organization.

Four Major Appointments for British American Oil

The board of directors of the British American Oil company an-

nounced four major executive appointments. M. S. Beringer, retiring president, was re-elected chairman of the board. E. D. Brockett, formerly vice-president, Gulf Oil corporation, was made president and chief executive officer. Other new appointments were J. W. Morgan, formerly general manager of B-A's manufacturing, as vice-president, and J. R. Yarnell, formerly services manager for B-A's production department in Calgary and assistant secretary, as treasurer.

An oil man with many years of experience on this continent and abroad, Mr. Brockett adds executive strength to B-A's expanding operations in Canada and the United States and to the company's position in the international petroleum scene generally.

After graduation from Texas A & M, Mr. Brockett began his career in 1934 as a roustabout in the oil fields of West Texas and was a petroleum engineer from 1936 until World War II, during which he rose to the rank of colonel. After the war he held various administrative and engineering posts in the industry, most recently as assistant to the president and production manager of the Mene Grande Oil company, Venezuela, and as vice-president and coordinator of all production for Gulf Oil corporation in the United States and throughout the world.

A. P. Williams, Jr., Joins Penola as a Vice President and Director

Aden P. Williams, Jr., marketing coordinator of International Petroleum company, Ltd., an affiliate of Standard Oil company (N. J.), has transferred from International's headquarters at Coral Gables, Fla., to accept a post in New York as a vice president and director of the Penola Oil company.

Penola is a marketing subsidiary of Esso Standard Oil company, principal U. S. refining and marketing affiliate of Jersey Standard.

With International Petroleum since January, 1956, Mr. Williams also served as the company's marketing manager in Peru. He was industrial sales manager in 1954 and 1955 for Esso Standard Oil, S. A., Havana, Cuba, which operates in the Caribbean and Central America.

The Havana assignment followed 21 years' service in Esso Standard's Virginia sales division.

While in Virginia he served as the division's industrial sales manager, and also as assistant manager and acting manager of the Roanoke sales district.

At Penola, Mr. Williams succeeds the late C. Park Hanneman, who died last Fall at age 51 after fourteen years as a vice president and director of the company. Penola markets lubricating oils, waxes, greases and other petroleum specialty products, both in this country and overseas.

Government Specification Product List Released by Bray Oil Co.

The Bray Oil company announces the release of the latest issue of its government specification product list. This list, carrying references on 250 specifications, has been found indispensable by many users of specification products in the fields of lubrication, hydraulics, corrosion prevention, and similar specialized areas.

In addition to the numerous references for current specifications, the list gives the MIL specifications equivalent for approximately 140 old Aeronautical (AN-), Air Force, Army, and Navy specifications.

In addition to being available at Bray factories at Los Angeles and Richmond, California, the products offered on the list are available to industries east of the Mississippi through the Royal Lubricants company, River road, Hanover, New Jersey.

V. R. Farlow Appointed Director of Petrochemical Sales for Gulf Oil Corp.

Mr. Victor R. Farlow was promoted to director of petrochemical sales effective April 1, Gulf Oil corporation announced. In this capacity he will direct marketing activities for Gulf's expanding petrochemical business. He was previously a sales representative in the petrochemicals department.

Mr. Farlow came to Gulf in 1954 after nine years service with American Cyanamid company in technical sales and sales management capacities. Previous to that he held various technical assignments with Caterpillar Tractor company.

Mr. Farlow is a native of Mt. Vernon, Illinois, and received his B.S. degree in chemistry from the University of Illinois in 1936.

J. L. Taylor, Jr., Joins Gulf

Another recent change in Gulf's petrochemicals department is the addition of James L. Taylor, Jr., who has accepted the position of sales representative. He previously was with Virginia-Carolina Chemical corporation in Richmond for nine years, during which time he was engaged in sales and sales supervision. Mr. Taylor also spent a brief period in atomic energy work with the Monsanto Chemical company. He was graduated from Virginia Military Institute in 1948 with a B.S. in chemistry.

Dr. Spencer Milliken Joins Foote Research Group

Dr. Spencer R. Milliken has been appointed research and development-sales staff coordinator by Dr. E. M. Kipp, director of research, Foote Mineral company. Dr. Milliken joins Foote after five years with the Aluminum Company of America research laboratories in Kensington, Pa.

A graduate of Georgia Institute of Technology, Dr. Milliken received his M.S. in physical chemistry from Emory university in 1951 and his doctor's degree from the Pennsylvania State university in 1954. He is a member of the American Chemical society. The American Institute of Mining and Metallurgical Engineers and the New York Academy of Sciences.

Dudley Dunlop Retires

Dudley Dunlop, eastern division manager of Mallinckrodt Chemical works, retired April 30, after more than 50 years of continuous service with the company.

Mr. Dunlop will continue as a consultant for Mallinckrodt, with an office in the company's New York headquarters at 72 Gold street. Shortly after his retirement he will make an extensive trip calling on many of his friends in the industry.

Industry News

Foote Mineral Planning New Technical Center

Foote Mineral company is making plans for a new technical center and may start construction next year, L. G. Bliss, president, told shareholders at the Philadelphia firm's 42nd annual shareholder meeting.

The new laboratories will eventually be erected on the company's recently purchased 54-acre tract of land near Exton, Pa., and will house the firm's research and development department and the central engineering department.

"Our policy of investing a substantial part of our earnings in research has been our trademark in the past, and we see no reason to interrupt a successful policy even in the face of an economic lull," Bliss stated. "We intend to provide our scientists and engineers with efficient and modern tools, and we hope to continue to attract top flight scientific talent."

New Application Manual Issued on Molykote Bonded Coatings

Bulletin 115, a handy 25-page manual which covers in detail the preparation of metal surfaces for the proper application of Molykote resin bonded lubricant coatings, has been published by the Alpha-Molykote corporation.

The manual includes instructions for degreasing all metals; phosphating of stainless steels; sandblasting of chrome plate, nickel plate and stainless steel; anodizing of aluminum and aluminum alloys; dichromate treatment for magnesium and magnesium alloys; bright dip-treatment for copper and copper alloys; and the phosphate fluoride coating of titanium and titanium alloys.

Copies of Bulletin 115 are available from the Alpha-Molykote corporation, 65 Harvard Ave., Stamford, Conn.

New Series of Alcohols Developed by Du Pont

Development of a new series of high fluorine-containing alcohols that provide a convenient means

of introducing fluoroalkyl groups into an organic molecule has been announced by Du Pont. Equally important, they show promise as intermediates in development of new plastics, surface active agents, lubricants, elastomers, and plasticizers with exceptional thermal and chemical stability.

Outgrowth of ten years of research on the free radical telomerization of tetrafluoroethylene in methanol, the fluoroalcohols are being offered in development quantities. Initially, two compounds—C_3 Fluoroalcohol [HCF_2-CF_2-CH_2OH (1H, 1H, 3H,-Tetrafluoro-1-propanol)] and C_5 Fluoroalcohol [HCF_2-CF_2-CF_2-CF_2-CH_2OH (1H, 1H, 5H,-Octafluoro-1-pentanol)] are available at $30 per pound.

Representing the lowest members of a series of trihydrofluoroalcohols containing an odd number of carbon atoms, the fluoroalcohols undergo reactions characteristic of primary alcohols, the company's organic chemicals department said. They are, however, about 10,000 times more acidic than ethanol and may require modification of conditions generally used with hydrocarbon alcohols to attain similar chemical reactions.

The new fluoroalcohols, Du Pont chemists explained, can be oxidized by potassium permanganate or nitric acid to yield corresponding fluorocarboxylic acids with boiling points in the range of 133 to 166° C. and unlimited solubility in water. Organic acid esters of the fluoroalcohols can be prepared by standard methods, with the esters of unsaturated acids lending themselves to polymerization into plastic or elastomeric materials with exceptional chemical and thermal stability. Polymers of the perfluoroalkyl acrylates and methacrylates can be prepared readily by emulsion polymerization, chemists added.

Fluoroalcohol esters of polybasic acids are of interest as high temperature lubricants and stable fluids because the esters do not oxidize at temperatures approaching 200° C. and and are stable to pyrolysis at

300° C. Diesters of the fluoroalcohols are superior to petroleum oils in lubricating ability and are less susceptible to fire and explosion hazards than are other types of lubricants, according to Du Pont's research.

Other promising derivatives, the company said, include phosphoric acid esters, salts of which show promise as specialty surface active agents, particularly in those polymerizations in which conventional dispersing agents cause chain termination: alcohol sulfates; fluoroalkyl urethanes; fluoroalkyl ethers, and tri (fluoroalkyl) cyanurates.

While toxicological studies carried out at Du Pont's Haskell laboratory for toxicology and industrial medicine indicate a low order of toxicity for both the C_3 and C_5 Fluoroalcohols, the company cautioned users to provide good ventilation in areas where the chemicals are exposed to temperatures over 200° C. Preparation of alkali metal salts of the fluoroalcohols is hazardous, they warned.

Physical properties of the pure fluoroalcohols are as follows:

	C_3 Fluoroalcohol	*C_5 Fluoroalcohol*
Formula Weight	132.06	232.08
Fluorine Content	57.5%	65.5%
Melting Point	−15° C.	–
Boiling Point	109-110° C/760 mm.	140-141° C/760 mm.
Density @ 20° C.	1.4853 g./ml.	1.6647 g./ml.
Refractive Index, n_D^{20}	1.3197	1.3178
Surface Tension @ 20° C.	27.6 dynes/cm.	24.5 dynes/cm.
Physical form	clear, colorless liquid	clear, colorless liquid

18% Increased Production Claimed With New Buxton Grease Mill!

A new high speed, increased production grease mill has just been announced by D. C. Buxton, president of the Buxton Machine & Tool company of Buffalo, N. Y. Said Mr. Buxton, "We developed this new mill to meet the demands of grease makers for a machine that would improve the quality of their product and to process fibrous soda chassis greases, lithium and barium multi-purpose formulae."

"Following our extensive tests, the mill was placed on regular production lines in Niagara Frontier grease manufacturing plants. Engineers have reported a saving of 18 per cent in production time of batches, also a higher quality and uniformity of finished products."

Other advantages claimed for the new mill include economies made possible with revised formulas that

PUT YOUR SHOP "IN THE CHIPS" WITH NEW ATLANTIC CUTTING OILS

For complete information on these improved oils, contact The Atlantic Refining Company, 260 South Broad Street, Philadelphia 1, Pa., or any of the offices listed.

PROVIDENCE, R. I.
430 Hospital Trust Bldg.

READING, PA.
First and Penn Aves.

SYRACUSE, N. Y.
Salina and Genesee Sts.

PITTSBURGH, PA.
Chamber of Commerce Bldg.

CHARLOTTE, N. C.
1112 South Boulevard

ATLANTIC

LUBRICANTS • WAXES
PROCESS PRODUCTS

can be worked with this unit. Process cycles can be speeded with this mill which has a 60 to 80 gallon per minute put-through, depending upon the type of product being processed. Basic formulations can be revised resulting in numerous improvements in many products. Engineers report that with the new conditions of shear and turbulence provided, this mill produces surprising results over the use of normal rotating and counter-rotating paddle and scraper action equipment, greatly speeding processing cycles. Many greases may be produced at lower steam pressures, and it has been found that fewer batches are off specifications.

Features of the new Buxton mill include new design, precision drilled and hardened disc-plates and a direct drive from motor to mill with a Morse chain safety coupling incorporated in the drive line. Close tolerances are observed throughout manufacture. Easy inspection and maintenance is permitted through easily removable outlet and inlet housing flanges. These flanges are of standard sizes, although special sizes can be specified as optional equipment.

The Buxton mill is powered with a 30 hp, 1750 rpm General Electric, three-phase, 220-volt, 60-cycle motor. Other makes are optional. In operation, the unit is noticeably free of vibration and has been particularly valuable in the processing of new formulae. The Buxton Machine & Tool company is located at 2181 Elmwood avenue, Buffalo 21, New York.

Sebacic Acid Price Reduction

A price reduction for sebacic acid effective April 28, 1958 has been announced by Harchem division, Wallace & Tiernan Inc., Belleville, N. J. The reason for the reduction is a decrease in the cost of basic raw materials. The actual price reduction amounts to three and one-half cents per pound.

Prices of sebacic acid esters such as dibutyl sebacate, dimethyl sebacate and dioctyl sebacate are also being reduced. All sebacic acid ester prices are now being quoted on a delivered basis.

Sebacic acid is a di-basic, straight chain aliphatic acid which provides more permanence and durability than any other di-functional intermediate. Sebacic acid finds wide use in synthetic lubricants, nylon fibres, moulding powders, polyurethanes, polyesters and alkyds. Sebacic acid esters are used as plasticizers for vinyls, synthetic rubbers, acrylics and a host of other plastics.

First American Cab-o-Sil Now in Production

Godfrey L. Cabot, Inc., Boston, Massachusetts, manufacturer of carbon black and chemicals, has announced that the first American-made Cab-o-Sil is now in production. The chemicals division of Cabot Carbon company, a subsidiary of Godfrey L. Cabot, Inc., recently completed a plant at Tuscola, Illinois, for the production of silicon dioxide and eventually other metallic oxides.

This plant is Cabot's latest advance in supplying American industry's demand for ultra-fine pigments. It has an annual capacity of five million pounds of silicon dioxide.

In 1950, Cabot completed a cross-licensing arrangement with Degussa of Germany, in which Cabot obtained the rights to sell and produce the fine silica pigment which the Germans called Aerosil. In 1952, Cabot introduced this product to the American market by importing it from Germany. In 1953, the trade name Cab-o-Sil® was adopted and a full-scale market development was begun. In 1955, the American demand for the product had increased to the point where production in this country became economical.

A silicon dioxide, essentially pure (99+%), Cab-o-Sil is as fine as cigarette smoke.

Continued on page 158

Cab-O-Sil in Production

Continued from page 156

Its present applications include: reinforcing rubber polymers, stabilizing lubricating greases, coating reproduction paper, adjusting viscosity of paints and inks and controlling properties of a wide variety of industrial powders and liquids.

"Chemetron" Is Picked as New Name for NCG

National Cylinder Gas company announced that directors had voted that the company name be changed, because it has been outgrown," and are asking stockholders to approve the name "Chemetron corporation."

President Charles J. Haines made the announcement at a Chicago press conference viewed on closed-circuit television by additional newsmen and businessmen at two locations in New York. He said the 24-year-old "National Cylinder Gas Company" name had been satisfactory while the firm produced only industrial gases and equipment using gases, but that addition through the years of many new product lines and services had made it "too restictive."

Haines said the name finally selected by the board of directors "won every test conducted by two research organizations. 'Chemetron' is appropriately made up of parts of the names of three of the many major industries served by the company—chemicals ('chem'), metals ('met') and electronics ('tron')."

The company and its subsidiaries have 81 plants located in 31 states, and 14 plants in other countries.

Four new divisions were formed, bringing the total to seven: NCG division, Tube Turns division, Pennsylvania Forge division, Perforating Guns Atlas division, Girdler Construction division, Girdler Process Equipment division and Chemical Products division. The company also has foreign subsidiaries operating in Canada, Venezuela, Colombia, England, Germany and Puerto Rico, and two domestic affiliates of which it owns 50 per cent: Tube Turns Plastics, Inc. and Midwest Carbide company.

The company expects to begin using the name "Chemetron Corporation" following the annual stockholder meeting on May 6.

Vulcan Containers Offers Literature on New Drums

Vulcan Containers Inc., pioneer Bellwood, Ill., steel shipping container manufacturer, has prepared two pamphlets describing specifications of new drums recently added to its expanded product line.

One of the pamphlets reviews the advantages of Vulcan's new 55-gallon, tight-head Uni-Drums which interlock because of slightly offset rolling hoops. The new drums, when unitized, save shipping space and reduce storage and handling costs by eliminating costly wood pallets. Because of six-point contact between the new drums when unitized, rotation and vertical movement is minimized, thus reducing damage in shipment.

The other Vulcan pamphlet explains the uses and describes the accessories for open and tight-head, 55-gallon drums, the single and double blade 55-gallon agitator drums, the open and closed-head, 15-gallon drums, and 100- and 120-pound capacity open-head grease drums.

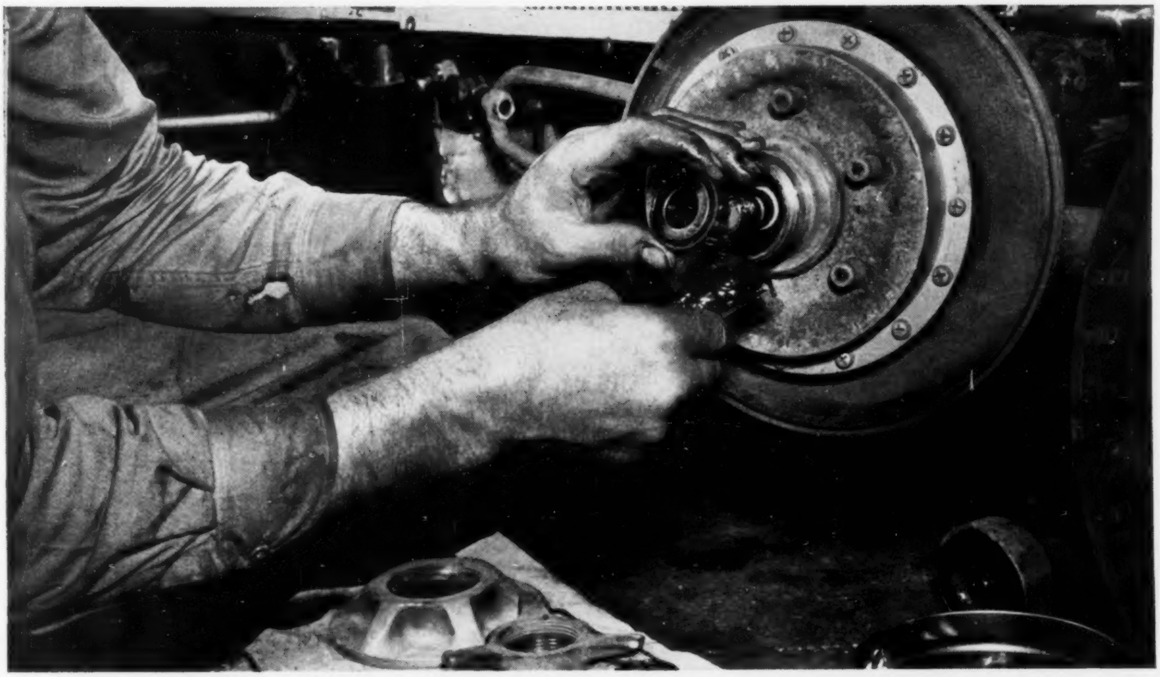
Both reference data sources may be obtained by writing Dept. PR1, Vulcan Contianers Inc., Bellwood.

API Catalogue Available

A new and up-to-date catalogue of the publications and materials of the American Petroleum Institute is now available through the trade association's New York headquarters.

The 58-page booklet contains thumbnail descriptions of each publication, the code number and costs, and specific instructions on how each should be ordered. It also points out that quantity discounts are applicable on many of the publications and materials.

Copies of the catalogue may be obtained gratis by contacting the Publication Section of the Institute at 50 West 50th Street, New York 20, New York.



Better Water-Resistant Greases With ADM's Hydrofol AB Acid

Many grease manufacturers have discovered how ADM Hydrofol AB Acid improves their water-resistant sodium and aluminum-based greases. The reason is that Hydrofol AB Acid is a combination of fatty acids with chain lengths ranging from C-14 to C-22. The C-20 and C-22 acids (arachidic and behenic) make up more than half of the total mixture.

This blend gives a far different structure than acids dominantly of one chain length. Hydrofol AB Acid gives you a mixture of desirable characteristics, with improved solubility plus really remarkable water repellency. Manufacturers of greases for water pumps, springs, wheel bearings, chassis, steering mechanisms, ball or roller bearings, and other places where water resistance is essential have turned to Hydrofol AB Acid to solve their problems.

These same manufacturers have learned to rely on ADM's leadership, reputation, and consistent quality. If you somehow have missed doing business with ADM, chances are you have a pleasant treat ahead of you. Find out for yourself why so many people in the grease industry order their fatty acids from ADM. And, for your future reference, here are the specifications for Hydrofol AB Acid:

SPECIFICATIONS

Titer	60-63 °C
Acid Value	178-185
Iodine Value	5 Max
Saponification Value	179-186
Spec Grav 100/20°C (av)	0.828
Color 5¼" Lovibond	25Y-2.5R
Calculated Molecular Wt.	302-314

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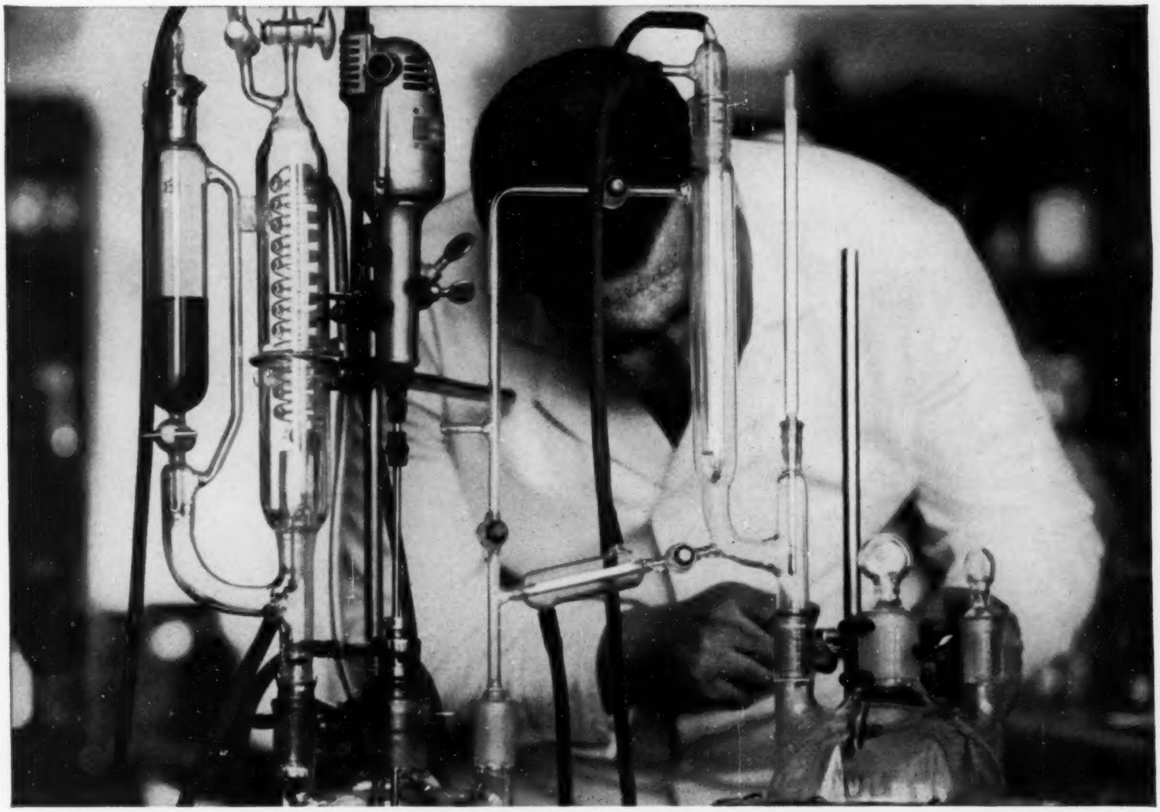

How organic chemists put lithium to work

Recent interest in organolithium compounds owes much to the fact that these compounds are soluble in hydrocarbons. The reactions of the organolithium compounds resemble those of organomagnesium compounds, yet have distinct advantages. In solution, lithium compounds exhibit a degree of reactivity intermediate between alkali and magnesium reagents.

Where it is necessary to use ether solvents, it is found that organosodium compounds decompose most ethers too rapidly. The organomagnesium compounds have too slow a reaction rate to be useful. With organolithium compounds the desired reaction can be completed before the ether is substantially attacked.

To produce intermediates for further reaction, certain ethylenic and aromatic systems add lithium and other alkali metals to give metallic derivatives. Lithium appears to react more readily than sodium or potassium and sometimes follows a different course of reaction.

Lithium metal and lithium alkyls seem to have the ability to direct the course of a polymerization. Isoprene has been polymerized to a product containing over 93% cis-1,4 addition product. Such polymers are considered to be the nearest approach to natural rubber. This stereospecific behavior of lithium catalysts may be useful in other organic reactions.

Reduction by means of alkali metals can be accomplished by using sodium in high-boiling solvents and in liquid ammonia. Recently it has been reported that the use of lithium often gives better yields. The versatility of lithium as a reducing agent in ethylenic and aromatic compounds is shown by the selective reduction of the carbon-carbon double bond of a conjugated ethylenic ketone using lithium in liquid ammonia. A contrasting example is the selective reduction of the carbonyl group of an unsaturated ketone using lithium aluminum hydride.

But this is only the beginning. Though the information on lithium in organics is relatively limited, its vast potential in this field is already well established. We'll be glad to share this information with you if it can help you in any way with your specific organic problem. Address letterhead request to Technical Literature Department, Foote Mineral Co., 402 Eighteen W. Chelten Bldg., Phila. 44, Pa.

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